3398

SITE REMEDIATION TECHNOLOGIES USED IN ONTARIO

JANUARY 1996

Ontario

Ministry of
Environment
and Energy

ISBN 0-7778-4838-4

SITE REMEDIATION TECHNOLOGIES

USED IN ONTARIO

JANUARY 1996

Cette publication technique
n'est disponible qu'en anglais.

Copyright: Queen's Printer for Ontario, 1995
This publication may be reproduced for non-commercial purposes
with appropriate attribution.

PIBS 3398E

SITE REMEDIATION TECHNOLOGIES

USED IN ONTARIO

Report prepared by:

U. Sibul
Landfill Technology & Site Remediation Section
Science & Technology Branch
Ministry of Environment and Energy

January 1996

ACKNOWLEDGEMENTS

The author wishes to thank the numerous companies and individuals who provided information and advice in this project. This report would not have been possible without their essential contributions.

SITE REMEDIATION TECHNOLOGIES USED IN ONTARIO

TABLE OF CONTENTS

	Page
EXECUTIVE SUMMARY	(viii)
INTRODUCTION	1
COMMON SITE REMEDIATION TECHNOLOGIES	2
Common Soil Treatment Technologies	5
Bioremediation	5
Soil Vapour Extraction	9
Low Temperature Thermal Desorption	13
Air Sparging	15
Common Ground Water Treatment Technologies	16
SUMMARY AND CONCLUSIONS	18
BIBLIOGRAPHY	25
APPENDIX A: CASE STUDIES IN ONTARIO	A1
APPENDIX B: CASE STUDIES IN OTHER JURISDICTIONS	B1
APPENDIX C: NCSRP CASE STUDIES OF EMERGING TECHNOLOGIES	C1

LIST OF FIGURES

Page

Figure 1. Schematic diagram of a bioremediation system operated in conjunction with other remediation technologies (reprinted with permission from Groundwater technology Inc.) 8

Figure 2. Schematic diagram of basic soil vapour extraction system 10

Figure 3. The effectiveness of soil vapour extraction compared to the volatility and water solubility of the contaminant 11

Figure 4. Schematic diagram of a simple low temperature thermal desorption process (from MOEE, October 1992) 14

Figure 5. Schematic diagram of an air sparging system in combination with soil vapour extraction (from CPPI Report No. 94-1) 17

LIST OF TABLES

Table 1. Examples of some common contaminants and their susceptibility to natural biodegradation 7

Table 2. The general effectiveness of soil vacuum extraction for removing different types of common contaminants from soil 12

Table 3. Summary of site remediation technologies used in Ontario 20

Table 4. Summary of site remediation technologies applications 22

ACRONYMS USED IN REPORT

BTEX	benzene, toluene, ethylbenzene, xylene
CCME	Canadian Council of Ministers of the Environment
CPPI	Canadian Petroleum Products Institute
GTI	Groundwater Technology Inc
HDPE	high density polyethylene
ICU	internal combustion unit
LNAPL	light non-aqueous phase liquid
LTTD	low temperature thermal desorption
MOEE	Ministry of the Environment and Energy (Ontario)
NCSRP	National Contaminated Sites Remediation Program
ND	non-detectable
PAH	polynuclear aromatic hydrocarbon
PCE	perchloroethylene
ppb	parts per billion
ppm	parts per million
SVE	soil vapour extraction
TCE	trichloroethylene
TPH	total petroleum hydrocarbon
USEPA	United States Environmental Protection Agency
VOC	volatile organic compound

EXECUTIVE SUMMARY

In a study to document cases of soil and ground water treatment technologies used in Ontario, 24 companies were contacted to canvass information. The purpose of this study was to determine which technologies are in common use and thereby provide a data base for MOEE staff when remediation technologies are under consideration by site owners for the cleanup of contaminated sites. As a result of this survey, 4 soil treatment technologies and 2 ground water treatment technologies were found to be in common use to deal with contaminated sites. Bioremediation, soil vapour extraction (SVE), low temperature thermal desorption (LTTD), and air sparging are used commonly for soil treatment, and activated carbon filtration and air sparging are used commonly to treat contaminated ground water. These technologies are used almost exclusively to treat contamination due to petroleum and other light-fraction hydrocarbons, and the use of SVE and LTTD appear to be most effective in the treatment of soils contaminated with these contaminants. In the application of all technologies, the design of individual systems can vary considerably and require site-specific engineering and maintenance to achieve the applicable soil cleanup guidelines in Ontario. Vendor claims regarding a specific technology to treat contaminated soil cannot be evaluated because there is virtually no substantive project data and often a combination of technologies is used, making the assessment of the effectiveness of individual technologies within a "black box" system difficult.

The excavation and disposal of contaminated soil at approved landfill sites is still the most common form of site remediation in the province because of a combination of factors that include cleanup costs, timing, post-cleanup liability, and dealing with contaminants that do not lend themselves readily to treatment by a cost-effective, proven technology.

Included as an appendix in the report is most recent documentation of demonstration projects throughout Canada of emerging site remediation technologies funded by The National Contaminated Sites Remediation Program of the CCME.

SITE REMEDIATION TECHNOLOGIES USED IN ONTARIO

INTRODUCTION

A study was undertaken to document cases of soil and ground water treatment technologies used in Ontario to provide a data base for MOEE decisions on technologies that are used in the cleanup of contaminated sites. Although the intent is to document cases pertaining to Ontario, technologies reported in other jurisdictions by the respondents are also included in the appendices. To obtain data for this study, a cross-section of site remediation companies that were either in the business of providing a technology, consultants who undertake cleanups for clients, or major site owners who undertake cleanups of their properties were contacted and asked to provide information in the form of reports or other documentation of site remediation cases from their files. In addition, the MOEE Regional offices, the Approvals Branch, and the Security Account Office were canvassed for the same information.

The following organizations were canvassed:
- Arcturus Environmental (*)
- Barenco Inc (**)
- BioQuest Environmental Co Ltd (*)
- Canada Soil Exchange Ltd
- Canadian Environmental Industry Association
- Canadian Petroleum Products Institute
- CH2M Hill Engineering
- Conestoga-Rovers & Associates Ltd (*)
- Gartner Lee Associates Ltd (*)
- Grace Dearborn Inc (**)
- Groundtrax Inc
- Groundwater Technology Canada Ltd (*)
- Greenwood Environmental Inc
- HTB AGRA Limited
- Imperial Oil Ltd (*)
- Laidlaw Environmental Services (*)
- Marshall Macklin Monaghan
- O'Connor Associates Environmental Inc(*)
- Ontario Hydro (*)
- Petro-Canada (*)
- Proctor & Redfern Ltd (*)
- Shell
- Sunoco
- Trow Consulting Engineers Ltd

(*) indicates response obtained and case study sheets included in this report
(**) indicates response obtained but not enough site-specific information is available to complete case study sheets; general site remediation project information is discussed in the text of the report

The generic information sought from each contact is shown on the case study sheets in the appendices. Field visits were made to a number of sites to asses the process being used and to gather data on the application of the process.

Not all contacts were able to provide the sought information and in some cases no information was provided at all, even though the contacts indicated that they were actively involved in site remediation in Ontario. Client confidentiality was cited as the prime reason for not being able to provide information freely on projects that a company had carried out in the past. The amount of detail on each case also varies due to the amount of information provided by each respondent, and the information provided by each respondent was not validated by the author of this report.

Although not explicitly stated by each respondent, it is assumed that the use of a particular technology has resulted in the reduction of the contaminant levels down to a criteria acceptable to a regulatory agency. In case of Ontario sites, the criteria would be governed by the Ontario cleanup guidelines in force at the time of the cleanup. The criteria are often different for sites throughout the USA, and are governed by the individual State or Federal guidelines. Information on the specific cleanup criteria was not available from the respondents.

An indication of the emerging site remediation technologies in Canada are shown in Appendix C. These information sheets relate to The National Contaminated sites Remediation Program and consist of research and/or demonstration projects that were funded jointly by the respective provinces and Environment Canada's DESRT program (Development and Demonstration of Site Remediation Technology). Some of these projects are on-going as of September 1995, and the information sheets are current as of this date. These information sheets are included only for information purposes and not discussed any further in the report.

COMMON SITE REMEDIATION TECHNOLOGIES

The cleanup of a contaminated site involves the removal and /or treatment of the source of the contamination, usually buried in the soil or on the surface of the ground, and the control and treatment of contaminated ground water. The removal and/or treatment of contaminated soil is usually a first priority and must be achieved before any attempts at ground water control and treatment can be undertaken. Most of the site remediation technologies documented in this report relate to the treatment of contaminated soil, with only minimal documentation and discussion of the treatment of contaminated ground water. Ground water treatment technologies will be documented in detail in a separate MOEE publication due to be published in the latter part of 1995.

Traditional soil treatment technologies claimed to be available commercially are:

In-situ technologies
- bioremediation *
- soil vapour extraction *
- soil leaching
- solidification/stabilization
- air sparging *

Ex-situ technologies
- bioremediation *
- low temperature thermal desorption *
- high temperature thermal desorption
- soil washing
- solidification/stabilization
- solvent/chemical extraction

* - commonly used in Ontario and discussed in this report

Traditional ground water treatment technologies available commercially include the following:

In-situ technologies
- active and passive free product recovery system (applicable to products that areimmiscible in water) *
- bioremediation
- air sparging *

Ex-situ technologies
- product/ground water separation
- oxidation
- air stripping
- activated carbon filtration *
- membrane technologies
- bioreactors

* - commonly used in Ontario and discussed in this report

There are excellent reviews of soil and ground water treatment technologies available in the literature and all of these technologies will not be reviewed in this report. Only those that have been found to be in common use in Ontario will be discussed.

In Ontario, the excavation and disposal of contaminated soil at licensed landfills is by far the most common method of site remediation. This method of cleanup is a reflection of the combination of generally competitive cost, the ease and timing for the cleanup, and the general lack of availability of proven technologies for the cleanup of contaminants that are not volatile or water soluble. With the excavation and disposal option there is no need for long term monitoring of the site after cleanup, and the assurance that the site is cleaned to established criteria can be readily demonstrated in most cases. For the purpose of this report, the excavation and disposal of contaminated soil is not considered a remediation technology and it is not discussed.

According to results of this study, the most common technologies used to treat contaminated soils in Ontario are bioremediation, soil vapour extraction, thermal desorption, and air sparging, and any combinations of these technologies at any one site. This is not to imply that these technologies are the only ones that are used, but rather that these are the ones most often used technologies in attempts to deal with contaminated soils in Ontario. These technologies are applicable mainly to petroleum hydrocarbons and similar light-fraction organic contaminants in which volatile organic compounds (VOC) are common and lend themselves readily to treatment by these technologies.

The specific technology or combination of technologies used at a site to treat soils are governed by the type of contaminant, the cost of using the technology, soil type and site conditions, and the time available for the remediation to reduce the contaminants to the required criteria. Excavation and disposal of the contaminated soil is still the most common method of site remediation in the Province when time is of essence and where non-volatile organics are the main soil contaminants.

Only after the source of contamination is removed from the soil can contaminated ground water be dealt with. The cleanup of ground water is in two separate parts; the control and extraction of contaminated ground water in the contaminant plume, and the treatment of contaminated ground water on the surface. The latter process is often referred to as "pump and treat" and in itself is not a remediation technology. In some situations the process of pumping and treatment of contaminated ground water is used as an interim measure to control the spread of contaminated ground water while the source of contaminant in the soil is being dealt with.

The most common ground water treatment technology involves ground water pumping and treatment on the surface, or in some cases air sparging as an in-situ treatment. Ground water treatment on the surface is usually in the form of activated charcoal filtration.

Ground water cleanup through solely pumping and surface treatment usually takes a long time as evidenced by an example provided by Laidlaw Environmental. The cleanup involved a trichloroethylene contamination at an eastern Ontario electronics systems manufacturing plant in which the ground water was pumped through a series of collection wells and treated through 45 micron filtration and activated carbon adsorption system at a design rate of 200 litres per minute. The original TCE concentration in ground water was in the 250 ppb range and had to be reduce to non-detectable levels. Although the annual TCE levels have been falling, the system has been in place for 4 years and estimates of 20 years to collect all of the TCE have been made. Capital cost of the system has been $1.0 million and an average annual operating cost of $200K to $300K make this remediation an expensive system with a long time-frame for total cleanup.

A similar example of projected long-term ground water remediation through pumping and treatment is documented in Case Study #21 at Rednersville.

Soil and ground water remediation technologies used in the field are never a simple technology described in text books, but rather systems engineered to meet specific needs of the site and contaminants of concern. These systems often need intricate engineering to combine and enhance the basic systems, followed by constant monitoring and system maintenance, to be effective and reduce the time required for successful remediation. As the complexity of the systems increase, so do the costs, and often this is the limiting factor in what technologies will be used to remediate soil and ground water contamination. The alternative is to simply excavate the contaminated soil and dispose of it at a licensed facility and deal with the contaminated ground water if it is a problem.

The following descriptions are of basic soil and ground water treatment technologies and not meant to reflect the variety of combinations of systems actually used in the field. Examples of the combinations of technologies are indicated in the case study sheets for individual projects.

COMMON SOIL TREATMENT TECHNOLOGIES

Bioremediation

Basic bioremediation systems are either "natural" or "enhanced", and in-situ or ex-situ. The classification of bioremediation into natural of enhanced systems is often confusing in the literature and for the purpose of this report a natural system refers to one that uses indigenous bacteria at a site, whereas an enhanced system utilizes other than indigenous bacteria to deal with the specific contaminant. Both systems may be used in combination with other soil treatment technologies such as air sparging and soil vapour extraction.

Most common bioremediation systems in use are aerobic processes that require some degree of engineering to provide the addition of nutrients, moisture, and oxygen (from air) for optimum performance, and most systems in use consist of combinations of these engineered systems. The successes of these systems vary according to the engineering and the site conditions and contaminants of concern.

In general, the following equation demonstrates the basic aerobic bioremediation formula:

ORGANIC POLLUTANT + BACTERIA + NUTRIENT + OXYGEN ⇒ CARBON DIOXIDE + WATER + BIOMASS

The use of non-indigenous bacteria slurries and mixtures is often used to deal with organic contaminants other than the light fraction organics, and the formulae for these mixtures are proprietary and designed specifically for the particular situation.

Natural bioremediation is most applicable to light-fraction petroleum hydrocarbons such as gasoline, diesel and heating fuels (Table 1), and enhanced bioremediation can treat soils contaminated with highly-chlorinated biphenyls, some pesticides, and other complex organic contaminants.

The claimed advantages of bioremediation include low cost and that it can be used in combination with other remediation technologies such as illustrated by the Groundwater Technology Inc. diagram shown in Figure 1. Its main disadvantage is that it may take a long time to accomplish the remediation, and it is not suitable for all types of contaminants, as for example, trace metals. In addition, the effectiveness of the cleanup due to biodegradation is uncertain and questions remain as to the actual process that is responsible for the of soil treatment. Because most of the bioremediation cases pertain to petroleum hydrocarbons that are volatile, the amount of volatilization versus biodegradation is not clear and the volatilization of hydrocarbons may be enhanced by the addition of air that is also necessary to provide oxygen for the aerobic bacteria.

An in-situ, enhanced bioremediation process is provided by Bio Quest (case studies #1 and #3). The process involves the injection of oxygenated water, nutrients and microbes into the unsaturated soil to treat soils contaminated with petroleum hydrocarbons. The process does not apply to other types of contaminants because the microbes are specially adapted to deal only with light-fraction hydrocarbons. Treatment durations are claimed to vary generally from 30 to 45 days to achieve soil cleanup criteria in Ontario.

A typical ex-situ, natural bioremediation process is operated by Petro-Canada at a soil remediation site in Mississauga (Study Case # 15). The process involves a fully engineered site where excavated soil contaminated with petroleum hydrocarbons is placed in a lined cell. Regular tilling, the addition of nutrients and moisture to the soil provide indigenous bacteria the conditions required for growth and biodegradation of the hydrocarbons. Treatment duration is approximately 2 to 3 weeks.

In both of the above examples of bioremediation, petroleum hydrocarbons are the main contaminants of concern and the cleanup criteria involve levels II and III of the Ontario Interim Guideline for the Assessment and Management of Petroleum Contaminated Sites in Ontario.

The application of the Daramend bioremediation technology by Grace Dearborn to deal with chlorophenols (CPs) and polynuclear aromatic hydrocarbons (PAHs) has been demonstrated at the former Domtar Inc. wood preserving site in Trenton, Ontario, and on sediments from Hamilton Harbour. This technology was developed under the sponsorship, and is owned by, the Government of Canada, with partial research funding provided by the Ontario Ministry of the Environment and Energy. Grace Dearborn Inc. has acquired the licence for worldwide application of this technology. The two demonstration projects indicated significant reductions in CPs and PAHs and this technology should provide an alternative for the treatment of soils contaminated with these chemicals. Estimated cost using the Daramend bioremediation technology at the two sites was approximately $105/tonne.

Table 1. Examples of some common contaminants and their susceptibility to natural biodegradation

---

RELATIVELY NON-BIODEGRADABLE

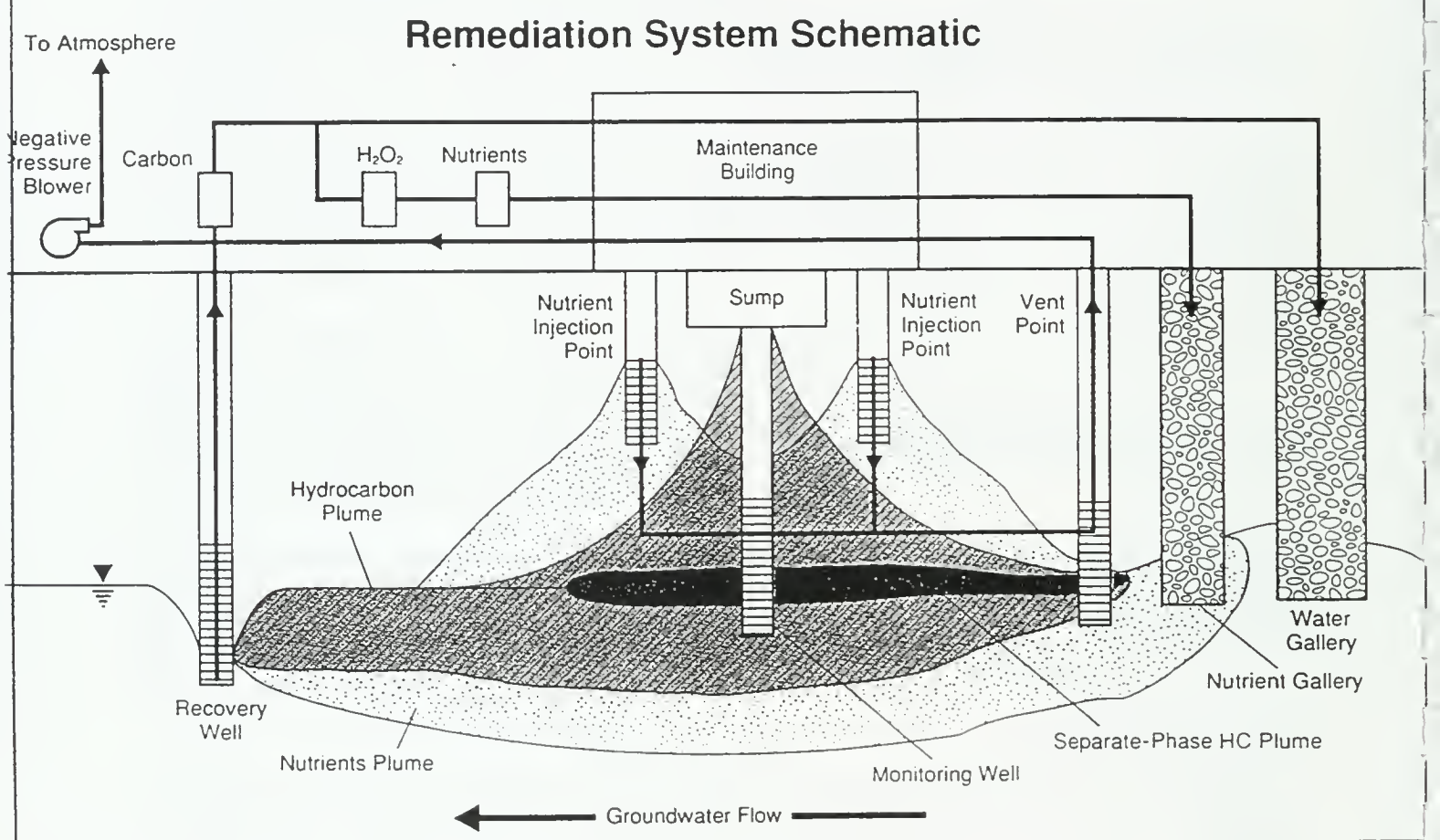
CARBON TETRACHLORIDE
HEXANE
O-XYLENE
M-XYLENE
ETHYLBENZENE
HIGHLY CHLORINATED BIPHENYLS
VINYL CHLORIDE
DDT

MODERATELY BIODEGRADABLE

ETHYL ETHER
GASOLINE
MINERAL SPIRITS
STYRENE
ETHYLENE GLYCOL

BIODEGRADABLE

P-XYLENE
TOLUENE
JET FUEL
KEROSENE
NAPHTHALENE
BENZENE
BIPHENYL
ACETONE



The bioremediation system design includes the following primary functions: groundwater recovery, treatment, and reinjection; vapor extraction and discharge; stimulation of *in situ* bioremediation by subsurface introduction of inorganic nutrients and oxygen; and separate-phase hydrocarbon recovery.

Figure 1. Schematic diagram of a bioremediation system operated in conjunction with other remediation technologies (reprinted with permission from Groundwater Technology Inc.)

Soil Vapour Extraction (SVE)

Soil vapour extraction is used generally as an in-situ technology that involves the removal of volatile organic contaminants from unsaturated subsurface soils or limited amounts of shallow ground water by the vacuum extraction of soil vapours from the soil. Sometimes SVE is used in combination with air forced through the soil matrix to provide oxygen and enhance the movement of air through the system. A typical simple SVE system is shown in Figure 2. The field applications of in-situ SVE systems are almost never simple and are usually engineered together with separate-phase contaminant recovery, air injection systems and/or other treatment technologies such as in-situ bioremediation. (Figure 1). The effectiveness of soil vapour extraction systems may be enhanced by air sparging if the soil is contaminated below the water table.

The collected vapours often contain moisture that requires separation from the vapour phase and both the vapours and liquid require individual treatment before being discharged. The vapours can be treated by an activated carbon bed, a catalytic converter, or by an internal combustion unit (ICU) before being discharged into the air. The carbon treatment is effective when small volumes of lower concentration vapours are involved, and the ICU is used when larger volumes of high concentration vapours are extracted. The liquid is usually treated in an aeration unit or through an activated carbon system before being discharged.

Soil vapour extraction systems are governed to a large degree by the volatility and solubility of the contaminant (Figure 3), and are most effective on volatile organics such as gasoline, fuel oils, solvents and other light-fraction organics (Table 2). They are usually not effective by themselves in removing contaminants from ground water. For soil vapour extraction systems to work, the soil has to be unsaturated, porous (hydraulic conductivity greater than 10^{-4} cm/s), and the site conditions have to be such that the soil vapours can be readily captured by the extraction system. Although vertical-pipe collection system are most common, horizontal piping collection systems can be used, especially in inaccessible locations.

A typical soil vapour extraction system is indicated in Case Study # 6. The process consists of well points drilled into the unsaturated zone to extract BTEX compounds, together with free product skimming on top of the water table. Air sparging below the water table helps to treat the contaminated soil and ground water at the site. Because of the large size of this site, remediation is expected to last up to 5 years.

The success of soil vapour extraction systems depend to a great extent on the degree of engineering, monitoring and adjustments made to the system after installation. Vapour capture efficiencies can vary considerably due to the density of the extraction points in the soil and the design of the extraction points. The ability to design and adjust the system to the existing soil conditions is of paramount importance to establish an efficient system that achieves the desired results in the required time. A prerequisite in all cases is a permeable soil, whether in-situ or ex-situ, to allow an even flow of air through the contaminated soil.

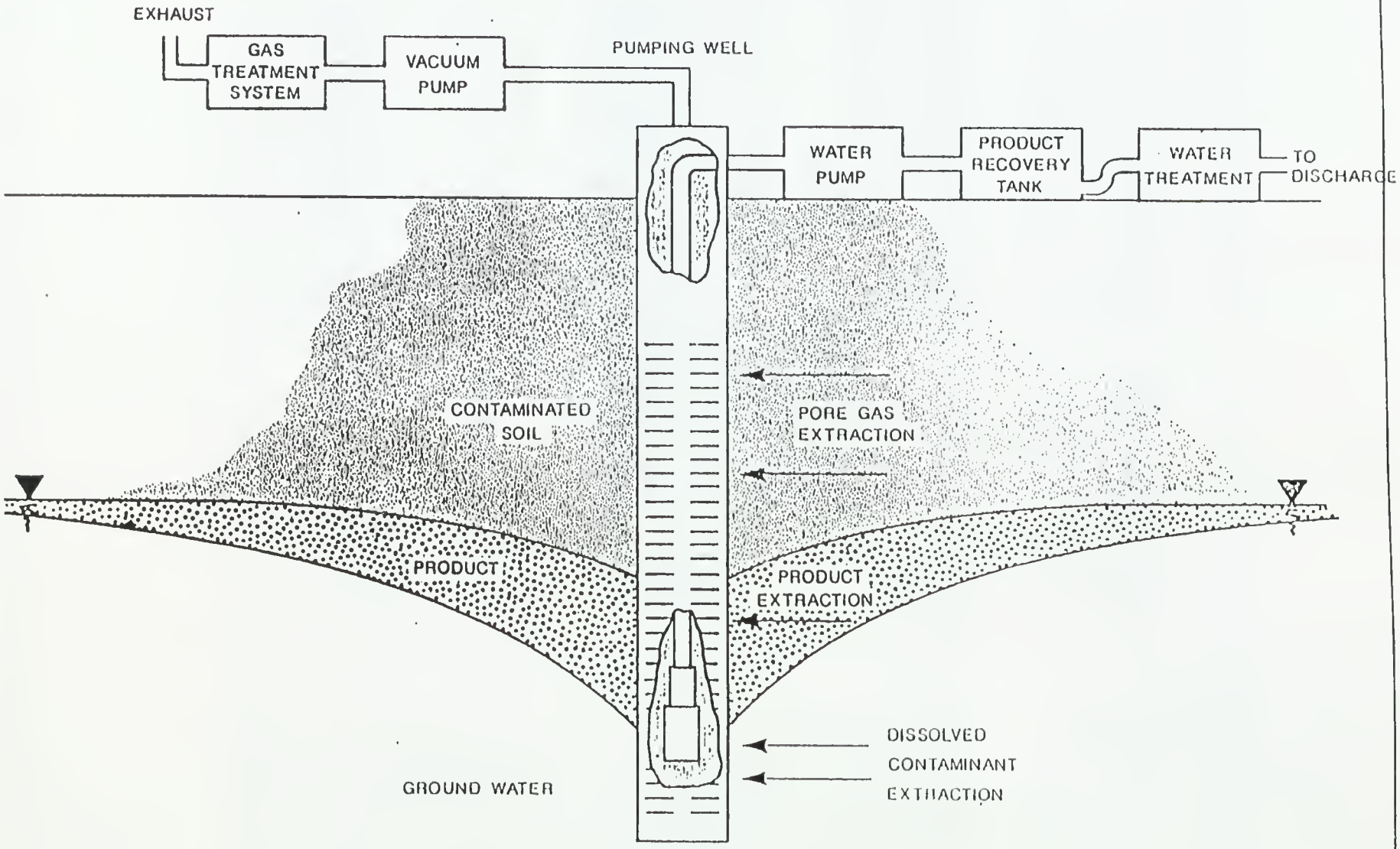


Figure 2 . Schematic diagram of basic soil vapour extraction system

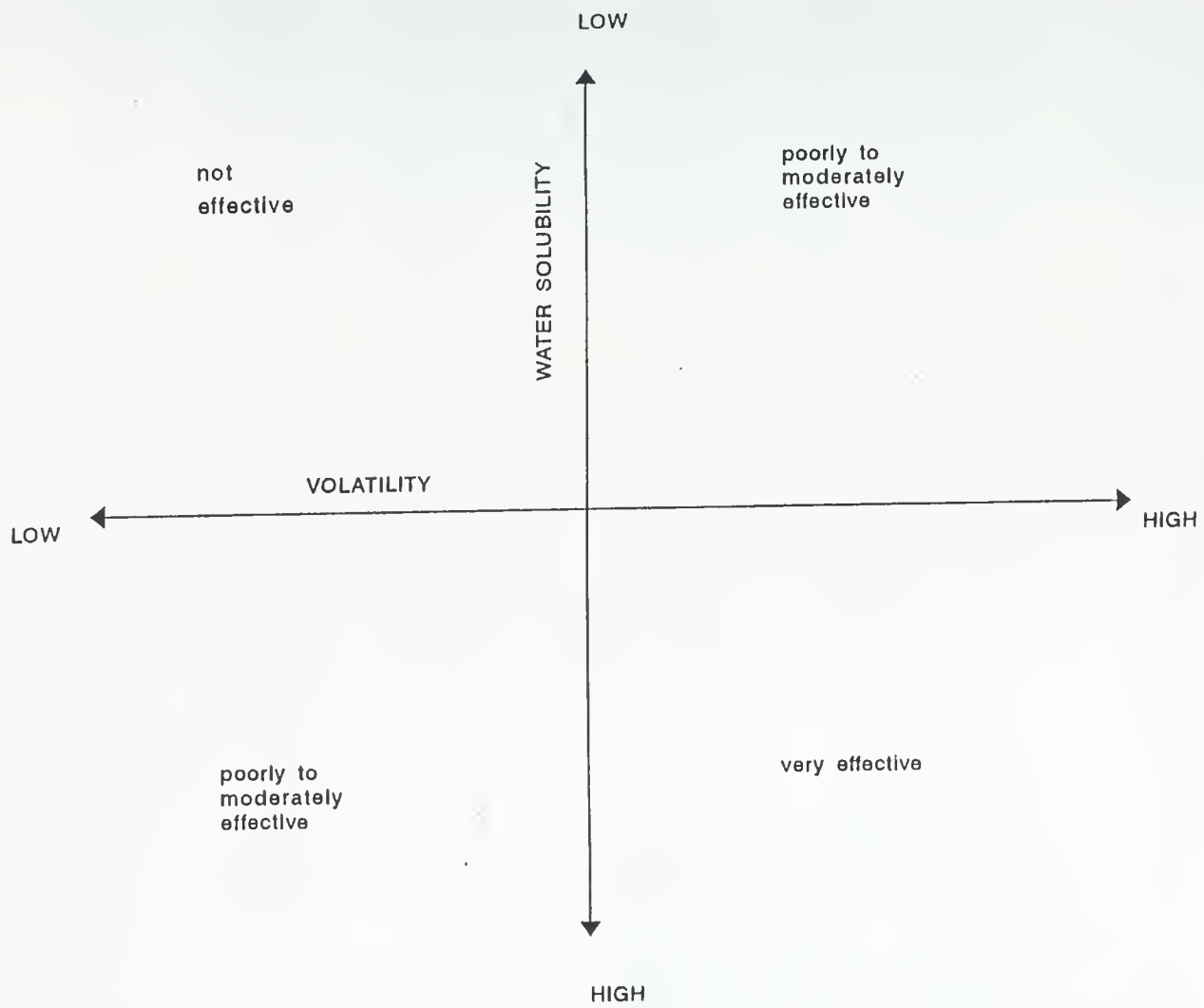


Figure 3. The effectiveness of soil vapour extraction compared to the volatility and water solubility of the contaminant

Table 2. The general effectiveness of soil vacuum extraction for removing different types of common contaminants from soil

Contaminant	Very Effective	Moderately Effective	Not Effective
Chlorinated Volatile Solvents (TCE, PCE, etc.)	X		
Volatile Petroleum Products (gasoline, etc.	X		
Semi-Volatile Petroleum Products (mineral spirits, fuel oil, etc.)		X	
Non-Volatile Organics and Inorganics (PCBs, dioxins, lead, arsenic, etc.)			X

Low Temperature Thermal Desorption

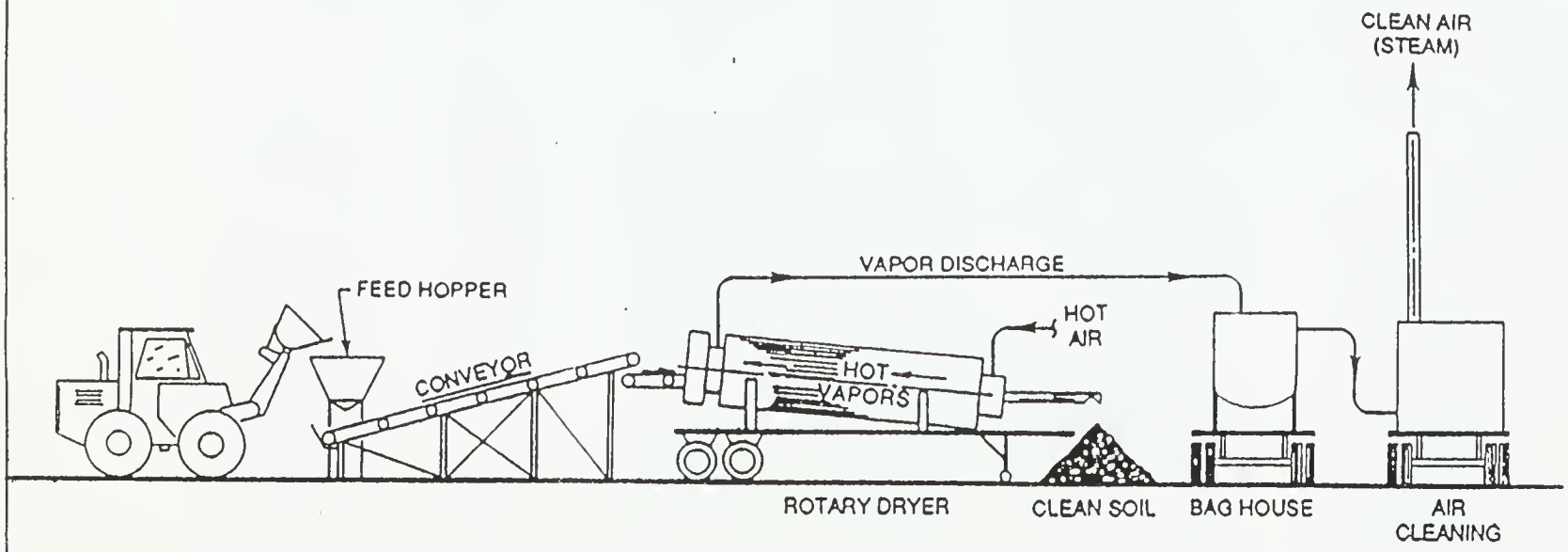
Low temperature thermal desorption (LTTD) has been used effectively in Ontario in numerous cases to deal with contaminants that are not readily handled by bioremediation or soil vapour extraction systems. There are a number of LTTD units that are approved by the Ontario Ministry of the Environment and Energy for use in Ontario. This process requires the excavation of the contaminated soil and consists of heating the soil to a temperature in the range of 300°C to 400°C to volatilize the contaminants. The vapours are collected as gas and are passed through an air emission control system and recovered, or through a secondary treatment unit where they are incinerated. The clean soil is usually left on site as fill. A basic LTTD is shown schematically in Figure 4. Most often these systems are mobile and are set up at the site being remediated. Each individual proprietary system varies in design and engineering.

The efficiency and rate of treatment by LTTD are determined by soil moisture, soil type and homogeneity, and the type and concentration of the contaminant. In general, high soil moisture, fine soil such as clay, and high concentrations of contaminants can all decrease the efficiency of contaminant removal from the soil. Each LTTD system deals somewhat differently with these limitations to increase treatment efficiencies. Thermal desorption is not effective in the treatment of soils containing free product such as gasoline or coal tars because these products contain some chemicals that do not lend themselves to volatilization at the low process temperatures.

A typical case of the application of LTTD has been demonstrated by the treatment of petroleum hydrocarbon contaminated soils at the Keele Valley landfill north of Toronto. The Soil Recycling Company, a subsidiary of Barendco Inc., operated the "Soil Recycler" at the site for approximately 2 years (1989-1991) and treated contaminated soil that was destined for the landfill. The LTTD was a mobile unit and consisted of primary and secondary treatment units, cyclonic separators, a cooling chamber, and a baghouse to remove dust. In the process, contaminated soil is fred through a primary treatment unit where the soil is tumbled in a drum while heating occurs. Clean soil is discharged from the drum while the hot air containing the evaporated organics is drawn from the primary treatment unit into high efficiency cyclones for dust removal. A secondary treatment unit then heats the gases to destroy the organics by oxidation. Finally, the gases pass through a cooling chamber and baghouse to remove the fine soil particles from the air before being discharged.

The unit at Keele Valley was claimed to have a 99.99% removal efficiency of VOCs in the air discharge, and the normal throughput of contaminated soil was in the order of 40 tonnes per hour. The maximum concentration of hydrocarbon in the soil to be treated was not to exceed 15,000 ppm, beyond which concentration the removal efficiency would drop considerably.

There are a number of companies in Ontario that provide LTTD services and each system can provide similar results on soil contaminated with light-fraction hydrocarbons. As of September 1995, the MOEE is in the process of using LTTD technology to treat soil contaminated with oil tar and other organic contaminants at Port Stanley. This project should provide detailed data on the success of the system to treat soil contaminated with contaminants other than just petroleum hydrocarbons. The project is to be completed in December 1995.



LOW TEMPERATURE THERMAL PROCESS.

Adapted from ON-SITE TREATMENT OF SOILS 1989 MANUAL

Figure 4. Schematic diagram of a simple low temperature thermal desorption process (from MOEE, October 1992)

Air Sparging

Air sparging is used most often in attempts to remove VOCs from ground water and contaminated soil below the water table, and is claimed to be effective when used in combination with a soil vapour extraction (SVE) system. Air sparging, similar in principle to surface air stripping towers used to remove contaminants from contaminated water, involves the injection of air into the subsurface below the water table, which has the effect of transferring the contaminants from the subsurface soil and ground water into sparged air bubbles. The air bubbles rise to the water table and dissipate into the unsaturated zone where they can be removed by a SVE system (Figure 5). Compounds strongly adsorbed to the soil matrix tend to be more difficult to extract by air sparging.

The introduction of air into ground water also increases the oxygen content and thereby provides oxygen for natural aerobic biodegradation of contaminants by indigenous microorganisms in the subsurface. The rate of this biodegradation can further be enhanced by the addition of nutrients to the system and this is often the case in the treatment of contaminated soil below the water table.

Some of the conditions that affect the success of air sparging are:

- the shallower the water table the easier it is to recover the VOCs;

- the contaminants should have a high volatility; compounds that are very soluble in water are not easily stripped by air;

- soil should be permeable enough so that the injected air can move freely through the soil, and homogeneous enough so that air entrainment does not decrease the efficiency of the system;

- the contaminated aquifer should be unconfined for recovery of the VOCs.

In Ontario, only a few cases of air sparging are available for documentation and the use of the technology is mostly in combination with soil vapour extraction (see cases #6 and #32).

The effectiveness and general successes of air sparging, like soil vapour extraction, depend to a large degree on the proper engineering and maintenance of the system after installation. Air sparging is prone to air entrainment and the homogeneity of the soil has a major influence on the even distribution of injected air to contact all soil particles. Except possibly for sand, the continual tilling of soil containing silt/clay may be necessary to enhance the homogeneity of the soil and to break up lumps that develop after a while during the treatment process.

The evaluation of the effectiveness of an air sparging system, which is often combined with soil vapour extraction and the addition of nutrients to the soil or recirculated ground water to promote natural bioremediation, is difficult because there are no data on any sites to separate the effectiveness of each of the separate components. On the basis of cases documented in

this report, there seems to be a presumption that the addition of nutrient to soil or ground water will automatically enhance biological activity, without actually measuring the growth of microorganisms in the soil. Similarly, air injection points can plug with precipitate and bacterial growth and the continual maintenance of the system is required to maintain the efficiency of the system. Without this maintenance the time required for soil treatment is lengthened and in some cases the system may fail to achieve soil cleanup at all.

COMMON GROUND WATER TREATMENT TECHNOLOGIES

At most contaminated sites, ground water is contaminated through direct contact with the contaminant below the water table, or by the leaching of contaminants by rainwater from soil in the unsaturated zone. As a result, a plume of contaminated ground water is created in the direction of ground water movement. After the contaminants are removed from the soil, the plume of contaminated ground water will have to be recovered through pumping and treated to prevent contamination of nearby wells or surface water. If there is free product floating on top of the water table or somewhere beneath the water table, it has to be removed prior to the treatment of ground water itself. In most of the cases documented in this study the product is light hydrocarbons, as for example gasoline, that float on top of the water table, and these can be removed by direct pumping if there is sufficient thickness of the product, or skimmer pumps can be used to pump thin layers of free product off the water table. The contaminated ground water containing dissolved contaminants is pumped from the ground and treated on the surface before discharge back into the ground or to surface water.

A large variety of surface treatment methods are available, and a common method of treatment consist of activated carbon filtration. Air sparging is used sometime in attempts to treat contaminated ground water in-situ when the contaminants are petroleum and other light-fraction hydrocarbons.

A free product recovery system applies most often to petroleum or other floating hydrocarbons commonly referred to as light non-aqueous phase liquids (LNAPL). A variety of free product recovery systems are available commercially and consist generally of specialized product recovery skimmer pumps or total liquid pumps. Skimmer pumps separate the pure product (contaminant) from ground water in the pumping well, whereas a total fluid pump recovers both the product and ground water which are separated on the surface. Membrane technology is often used in the skimming type pumps, and some manufacturers claim the ability of recovering pure product down to a thickness of 3 mm. The technology does not apply to dissolved or suspended phase contaminants, nor to viscous product such as lubricating oil. In most cases the recovered ground water requires some treatment before discharge to the environment.

Carbon filtration is a proven technology to remove dissolved hydrocarbon compounds from water. This technology is limited to soluble non-polar compounds such as BTEX, and is readily available commercially. The process involves the sorption of dissolved organic contaminants in water on to a solid carbon medium. The carbon may be granular or powdered and must be

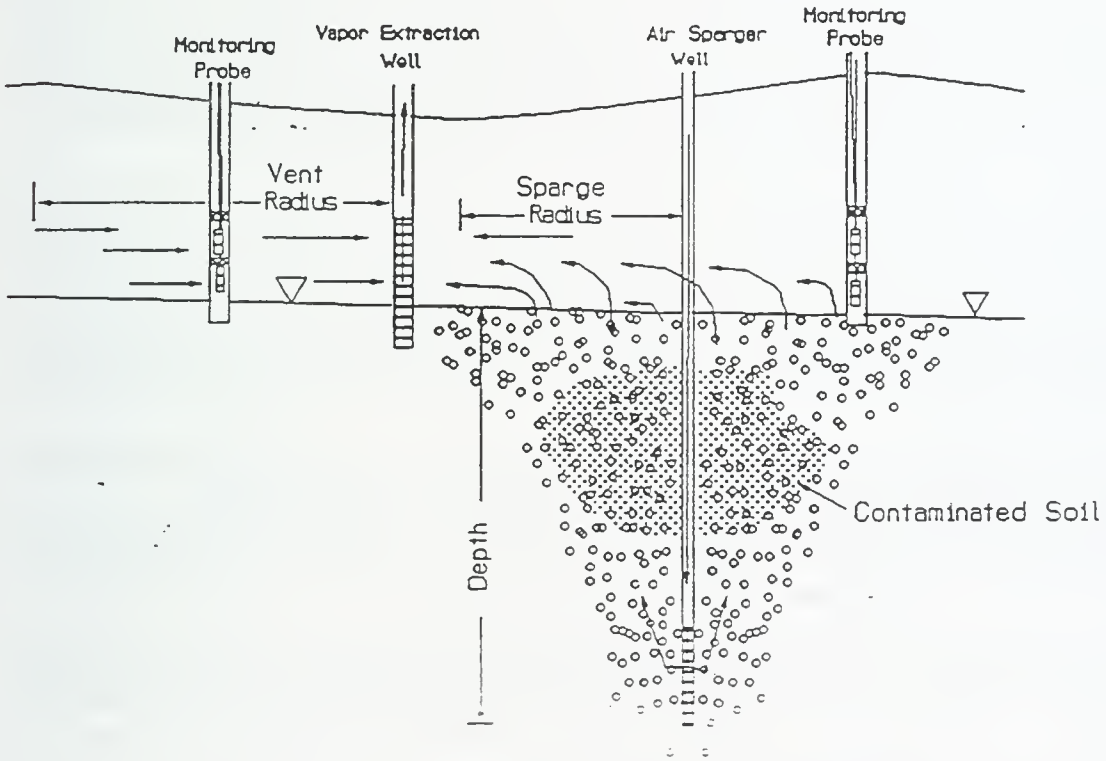


Figure 5. Schematic diagram of an air sparging system in combination with soil vapour extraction (from CPPI Report No. 94-1)

replaced regularly. Most carbon treatment systems have backwashing capabilities to remove particulate. Removal efficiencies are usually greater than 99% for trace levels of contaminants and performance is effected by temperature, contaminant concentrations, and biological fouling. Commercially-available systems can treat contaminated ground water up to about 100 gpm.

The treatment of ground water by air sparging is discussed in the soil remediation section.

SUMMARY AND CONCLUSIONS

A study was undertaken to determine the common soil and ground water treatment technologies used in Ontario to remediate contaminated sites. A summary of these technologies is shown in Table 3. Twenty-four(24) companies were contacted to enquire about site remediation technologies that they have used in the past; eleven (11) companies provided data that were used to fill out data sheets for cleanup technologies used in Ontario and other jurisdictions. These data sheets are shown in appendices A and B, and summarized in Table 4. Information on the demonstration of emerging technologies in Canada related to the Contaminated Sites Remediation Program are shown in Appendix C.

On the basis of this study, the following conclusions can be made:

•in Ontario, excavation and disposal of contaminated soil is still by far the most common form of site remediation to deal with contaminated soil;

•the common contaminants in soil that lend themselves most readily to treatment (rather than excavation and disposal) are petroleum and other light-fraction hydrocarbons;

•bioremediation, soil vapour extraction (SVE), low temperature thermal desorption (LTTD) and air sparging are technologies used commonly in attempts to treat contaminated soil;

•of these four technologies, soil vapour extraction and LTTD systems appear to be most effective in the treatment of soils contaminated by petroleum and other light-fraction hydrocarbons;

•the effectiveness of biodegradation versus volatilization in the treatment of soils contaminated by light-fraction hydrocarbons, especially in cases involving the addition of air necessary for aerobic biodegradation, cannot be readily determined because of the lack of appropriate data on operating systems in Ontario;

•the effectiveness of air sparging systems in the in-situ treatment of ground water and contaminated soil below the water table is difficult to assess as these systems are not operated usually by themselves, but rather in combination with SVE and bioremediation;

•vendor claims regading the effectiveness and efficiency of individual technologies within the application of a combinations of technologies is difficult to determine because there are virtually no data available that lend themselves to assessment on operating systems in Ontario;

•when a combination of technologies are used, the whole system acts as a "black box" in which the significance or effectiveness of individual processes in treating the contaminants cannot be determined;

•activated carbon filtration is an effective, well-established technology to treat contaminated ground water; the effectiveness of air sparging in the in-situ treatment of contaminated ground water is questionable and should be used in combination with a SVE system;

•although the use of the above-mentioned soil and ground water cleanup technologies are in common use by the soil remediation industry, the design of individual systems can vary considerably and require site-specific engineering and maintenance to achieve the applicable soil cleanup guidelines in Ontario; failures in site remediation are usually failures in engineering and maintenance rather than in basic technology;

•it cannot be assumed that because bioremediation, soil vapour extraction, LTTD and air sparging are in common use either singly or in combination with each other, they are all successful in treating the contaminated soil to below criteria; proper engineering/maintenance of systems, and time and cost available for the project are critical factors that determine the success of a remediation project; in cases involving simply the addition of nutrients and air to soil contaminated by light-fraction hydrocarbons, the effectiveness and the process of cleanup by biodegradation alone may be questionable;

•soil treatment successes are not "absolute" and depend to a great extent on what the client expectations are and how the project results can address these expectations; total cost, project duration and the ability of a technology or combination of technologies to reduce the contaminants to the regulatory criteria all combine to determine the success or failure attributable to an applied technology or combination of technologies;

•soil treatment technologies used in the field are usually not off-the-shelf, absolute systems and each case of contamination involves an engineered system of one or more technologies to produce results in the required time and cost available to the project.

Table 3. Summary of site remediation technologies used in Ontario.

A. SOIL TREATMENT

TECHNOLOGY	DESCRIPTION	EXAMPLES OF COMPANIES USING TECHNOLOGY
BIOREMEDIATION NATURAL	- in-situ and ex-situ technology - use of indigenous bacteria - addition of nutrient and oxygen (air) a common practise to promote bacteria growth - most suitable for light petroleum hydrocarbons such as gasoline, diesel and heating fuels	Barenco Imperial Oil Petro-Canada
ENHANCED	- in-situ and ex-situ technology - use of specially-formulated bacteria and bio-slurries containing nutrients and oxygen - technology can be used to treat soil containing chlorinated biphenyls, some pesticides and other complex organics	Bio Quest Environmental Grace Dearborn
SOIL VAPOUR EXTRACTION	- in-situ soil technology to remove volatile organics from contaminated soil - most applicable to chlorinated volatile solvents and volatile petroleum products - suitable mainly in unsaturated, permeable soil such as sands and gravels - often used in combination with air sparging and in-situ, natural bioremediation - requires engineering to optimize the efficiency of the extraction system - collected gases usually have to be treated before being discharged into the atmosphere	Arcturus Environmental O'Connor Associates Groundwater Technology
LOW TEMPERATURE THERMAL DESORPTION	- requires excavation of contaminated soil - soil is heater to 300 to 400 degrees C to volatilize contaminants - vapours are collected and treated before being discharged into the atmosphere - most applicable to volatile organic contaminants such as petroleum hydrocarbons and chlorinated solvents, and soils contaminated with PAHs	Canada Soil Exchange Enviro Desorption (Alberta) Greenplan Environmental Phillips Environmental Laidlaw Environmental
AIR SPARGING	- in-situ technology to remove volatile contaminants from ground water and soil below the water table - involves the injection of air into the subsurface below the water table - most effective when in combination with soil vapour extraction to collect the vapours - effective on organic contaminants that are volatile but not strongly adsorbed to the soil, or that have a high solubility in water - prone to air entrainment through the soil, decreasing the effectiveness of the technology	Groundwater Technology Conestoga-Rovers

Table 3. Summary of Site Remediation Technologies Used in Ontario (continued).

B. GROUND WATER TREATMENT

TECHNOLOGY	DESCRIPTION	EXAMPLES OF COMPANIES USING TECHNOLOGY
FREE PRODUCT RECOVERY	- the pumping of free product that usually floats on the surface of the water table - involves the use of total liquid or specialized product recovery pumps - total liquid pumps recover ground water and product, which have to be separated on the surface - product recovery pumps recover pure product only	any company that specializes in ground water cleanup, as for example: Arcturus Gartner Lee Groundwater Technology O'Connor Associates
CARBON FILTRATION	- an established technology in the purification of water - involves the sorption of dissolved organic contaminants in water on to a solid carbon medium	any company that specializes in ground water cleanup
AIR SPARGING	SEE DESCRIPTION IN PART "A" OF TABLE	SEE EXAMPLES IN PART "A" OF TABLE

Table 4. Summary of site remediation technologies applications.

CASE #	TECHNOLOGY	SOIL	GW	MAIN CONTAMINANT	COST	NOTE
1	in-situ bioremediation	X		BTEX, TPH	$32/yd^3	- treatment of unsaturated soil only - 7000 ppm TPH reduced to <1000 ppm
2	in-situ bioremediation	X		BTEX, TPH	unit cost not available	- surface treatment of contaminated soil - 14,000 ppm TPH reduced to <100 ppm
3	ex-situ bioremediation	X		BTEX, TPH	not applicable; demonstration project	- injection of bio-slurry into excavated soil - 2000 ppm TPH reduced to <50 ppm
4	soil vapour extraction carbon filtration	X	 X	BTEX, TPH	not available	- engineered cell for ex-situ soil vapour extraction - lowering of water table and treatment of ground water - 5200 ppb toluene in soil reduced to < 700 ppb; 1170 ppb toluene in ground water reduced to non-detectable
5	ex-situ bioremediation	X		PAH	$15-$30/tonne	- batch treatment of contaminated soil - total PAH in each batch reduced to <200 ppm
6	soil vapour extraction free-phase product recovery air sparging	X X	 X X	BTEX, chlorinated organics, xylene floating on water table	not available; project ongoing	- site remediation expected to last approx. 5 years - soil contains up to 24,000 ppm BTEX and up to 16 ppm chlorinated organics - ground water contains up to 114 BTEX and up to 24.5 ppm chlorinated organics
7	steam injection soil vapour extraction	X		oil containing PCB	not applicable; pilot study only	- pilot scale study of steam injection to determine engineering parameters to mobilize oil for recovery - difficulty in controlling steam breakthrough at surface
8	low temperature thermal desorption	X		xylene	$85/tonne	- 35,000 tonnes of soil processed - xylene reduced to <1.0 ppb
9	carbon filtration and flushing of contaminated ground water		X	BTEX, TPH	$150,000 start-up $70,000/yr to operate	- 5 ppm TPH in ground water treated to <0.001 ppm - treated water is re-injected into ground to flush contaminants from rock - approx. 6 year project
10	ex-situ bioremediation	X		BTEX, TPH	approx. $25/tonne	- biocell is below grade - vapour extraction system in cell - TPH in soil up to 16,000 ppm reduced to <100 ppm
11	ex-situ bioremediation (landfarming)	X		BTEX, TPH	approx. $15/tonne	- excavated soil spread on land and tilled - TPH in soil up to 5000 ppm reduced to <100 ppm - slow rate of treatment/seasonal

CASE #	TECHNOLOGY	SOIL	GW	MAIN CONTAMINANT	COST	NOTE
12	carbon filtration soil vapour extraction	 X	X	BTEX, TPH	unit cost not available; cost depends on length of operation; $70,000/yr operating cost	- contaminated ground water treated off-site; - initial TPH in ground water reduced to non-detectable; - soil vapours at explosive levels reduce to background concentrations
13	carbon filtration product recovery soil vapour extraction	 X	X X	BTEX, TPH	unit cost not available; cost depends on length on operation; $100,000/yr operating cost	- gasoline is separated from ground water by coalescing filters - BTEX in soil up to 165 ppm is reduced to <15 ppm after 12 months
14	soil washing	X		copper, arsenic, chromium	not available	- arsenic up to 2750 ppm reduced to <50 ppm - copper up to 1400 ppm reduced to <225 ppm - not effective in removing chromium at 795 ppm level
15	ex-situ bioremediation	X		BTEX, TPH	$25-$30/tonne	- research site for the treatment of gasoline contaminated soils derived from Petro-Canada service stations
16	low temperature thermal desorption	X		BTEX, TPH, xylene	$47/tonne	- BTEX in soil up to 15,000 ppm reduced to <5 ppm
17	carbon filtration product recovery	 	X X	mineral oil	not available	- oil/ground water separated by filter
18	soil vapour extraction	X		BTEX, TPH	unit cost not applicable; cost depends on duration of treatment	- technology applied to operating service stations to reduce gasoline vapours - gasoline vapours derived from contaminated soil reduced to <200 ppm
19	ex-situ bioremediation	X		BTEX, TPH	$25 to $50/tonne	- addition of nutrient and air - up to 25,000 ppm TPH reduced to <100 ppm
20	incineration	X		PCB	$2737/$m^3$	- incineration of PCB contaminated oil; contaminated soil treatment
21	carbon filtration		X	TCE, vinyl chloride	unit cost not available	- ground water is treated by point-of-use carbon treatment systems on domestic supplies - TCE up to 320 ppb reduced to non-detectable
22	carbon filtration		X	BTEX, TPH	$0.01/L to $0.25/L	- up to 1000 ppm TPH reduced to <10 ppm - oil/water separation necessary in some cases; oil recovered; water discharged into sanitary sewer
23	ex-situ bioremediation	X		BTEX, TPH	$2/tonne to $33/tonne	- up to 30,000 ppm TPH reduced to <50 ppm - engineered bio-cells with addition of nutrients and air

CASE #	TECHNOLOGY	SOIL	GW	MAIN CONTAMINANT	COST	NOTE
24	soil vapour extraction carbon filtration	X	X	BTEX, TPH	unit cost not available	- soil vapour extraction considered not effective in cleanup of soil below the water table to below 5000 ppm TPH because of free product on water table
25	ex-situ bioremediation	X		BTEX, TPH	unit cost not available	- 6500 ppm TPH reduced to <790 ppm after 10 months - engineered bio-cells
26	in-situ bioremediation air stripping	X	X	BTEX, TPH	unit cost not available	- claim 99% reduction in contaminants to <1 ppb TPH - ground water treated by on-surface air stripper - in-situ bioremediation includes addition of hydrogen peroxide and nutrient mixture
27	in-situ bioremediation air stripping soil vapour extraction	X X	X	BTEX, TPH	unit cost not available	- efficiency of system not available - treated ground water reinjected into ground to enhance bioremediation
28	low temperature thermal desorption air sparging in-situ bioremediation	X X	X	BTEX, TPH	unit cost not available	- efficiency of treatment not available - 27, 000 tons of contaminated soil treated
29	air stripping liquid-phase recovery		X X	BTEX, TPH	unit cost not available	- efficiency of treatment not available - oil/water separation resulted in almost 100% oil recovery - 410,500 gallons of oil recovered
30	in-situ bioremediation soil vapour extraction	X X		BTEX, TPH, MOTOR OIL	unit cost not available	- 52,000 ppm TPH reduce to <55 ppm - reinjection of treated ground water to enhance bioremediation
31	soil vapour extraction	X		BTEX, TPH	unit cost not available; total cost = $US180,000	- up to 2700 ppm BTEX reduced to <1 ppm
32	in-situ bioremediation soil vapour extraction air sparging	X X X	X	BTEX, TPH	unit cost not available; total cost = $US50,000	- all contaminants in ground water reduced to below detection limits
33	in-situ bioremediation soil vapour extraction	X X		BTEX, TPH	unit cost not available; total cost = $US250,000	- TPH up to 1000 ppb reduced to <0.4 ppb - 22 month duration of project
34	in-situ bioremediation	X		BTEX, TPH	unit cost not available; total cost = $US280,000	- contaminants reduced to below regulatory criteria

SELECTED BIBLIOGRAPHY

1.Barkley, Naomi P., Project Summary, Pilot Study on Demonstration of remedial Action Technologies for Contaminated Land and Groundwater, Volumes 1 and 2; USEPA Publication EPA/600/SR-93/012, September 1993

2.Canadian Petroleum Products Institute, Manual for Remediation of Groundwater Containing Dissolved and Free Phase Hydrocarbons, CPPI Report NO. 94-1, January 1994

3.Canadian Petroleum Products Institute, Manual of Petroleum Contaminated Soil Treatment Technologies; CPPI Report NO. 91-9, November 1991

4.Groundwater Technology Inc., Project Profile: Public Service Company of Colorado Fleet Maintenance Facility, GTI, January 1994

5.Loden, Mary E., September 1992, Project Summary, A Technology Assessment of Soil Vapor Extraction and Air Sparging; USEPA Publication EPA/600/SR-92/173

6.Miller, Michael E., et al., Project Summary, Soil Vapor Extraction Column Experiments on Gasoline Contaminated Soil; USEPA Publication EPA/600/SR-92/170, October 1992

7.MOEE, Application of Soil Remediation Technologies in the Greater Toronto Area, Waste Management Branch, August 1993

8.MOEE, Interim Guidelines for the Assessment and Management of Petroleum Contaminated Sites in Ontario, Hazardous Contaminants Branch, 1993

9.MOEE, Remediation Technologies for Contaminated Soils, Waste Management Branch, October 1992

10.USEPA, Superfund Innovative Technology Evaluation Program, Technology Profiles, Seventh Edition, EPA/540/R-94/526, November 1994

11.USEPA, Remediation Technologies Screening Matrix, EPA 542-B-93-115, July 1993

12.USEPA, Technology Screening Guide for Treatment of CERCLA Soils and Sludges, EPA/540/2-88/004, September 1988

APPENDIX A: CASE STUDIES IN ONTARIO

NOTE: the case study sheets contain a mix of metric and English units as provided by the respondents; to maintain integrity and accuracy of the information as provided by the respondents, no attempt has been made to change to one set of units

CASE STUDY #1
SITE REMEDIATION TECHNOLOGY APPLICATION IN ONTARIO

LOCATION OF SITE: Toronto

NAME OF COMPANY: BioQuest Environmental Co. Ltd.

MEDIUM CONTAMINATED: sand, silt, cobbles

MAIN CONTAMINANTS: gasoline hydrocarbons (BTEX)

AT RISK: NA; private soil remediation at former service station

TECHNOLOGY USED: in-situ bioremediation

BRIEF DESC. OF TECHNOLOGY: oxygenated water, nutrient and microbes are injected into the unsaturated soil; bio-product and oxygenated water are mixed and injected into the soil and the site is left to biodegrade on its own;

TREATMENT RATE: not applicable

BEFORE/AFTER CONCENTRATIONS: 7000 ppm TPH expected to be reduced to level I Ontario criteria of 100 ppm for total petroleum hydrocarbons

DURATION OF REMEDIATION: on-going as of July 1995; expected to be approximately 4 months

APPROX. COST: approx. $42/cubic meter

COMMENTS: soil contamination to 34 feet; injection at a 3 to 4 foot grid; contamination above and in the water table; injection holes created by 3000 psi water pressure; SOURCE OF INFORMATION: on-site visit with David Simpson of BioQuest, June 1995

CASE STUDY #2
SITE REMEDIATION TECHNOLOGY APPLICATION IN ONTARIO

LOCATION OF SITE: Longwood TS (SW London)

NAME OF COMPANY: BioQuest for Ontario Hydro

MEDIUM CONTAMINATED: soil, surface water

MAIN CONTAMINANTS: transformer oil (light hydrocarbon/mineral oil)

AT RISK: municipal drains, Sydenham River

TECHNOLOGY USED: in-situ bioremediation

BRIEF DESC. OF TECHNOLOGY: application of bio-formula and nutrients to surface soils and surface water; some injection of unsaturated soils at depth along road banks

TREATMENT RATE: not applicable

BEFORE/AFTER CONCENTRATIONS: max. 14,000 ppm TPH reduced to less than 100 ppm

DURATION OF REMEDIATION: approx. 30 days

APPROX. COST: $65,000; unit cost not available because treatment involved surface of soil, not volume

COMMENTS: for Ontario Hydro in London; transformer oil spill at station; mostly surface cleanup; transformer oil degrades quickly and is lighter than water (mineral oil); this technology is applicable only to light fraction hydrocarbons such as mineral oil and petroleum hydrocarbons; SOURCE OF INFORMATION: Terry Marshall of Ontario Hydro in London, June 1995

CASE STUDY #3
SITE REMEDIATION TECHNOLOGY APPLICATION IN ONTARIO

LOCATION OF SITE: Markham

NAME OF COMPANY: BioQuest for Ontario Hydro

MEDIUM CONTAMINATED: soil

MAIN CONTAMINANTS: petroleum hydrocarbons (gasoline, fuel oil)

AT RISK: NA; private site cleanup and decommissioning

TECHNOLOGY USED: on-site, ex-situ bioremediation

BRIEF DESC. OF TECHNOLOGY: contaminated soil excavated and place on tarp for bioremediation; injection of bio-formula into excavated soil

TREATMENT RATE: not applicable

BEFORE/AFTER CONCENTRATIONS: 2000 ppm TPH reduced to less than 50 ppm

DURATION OF REMEDIATION: approx. 45 days

APPROX. COST: not available; demonstration project for client

COMMENTS: contamination from leaking underground gasoline storage tanks;
this was a free demonstration project for Ontario Hydro; SOURCE OF INFORMATION: E. Leung of Ontario Hydro in Toronto, June 1995

CASE STUDY #4
SITE REMEDIATION TECHNOLOGY APPLICATION IN ONTARIO

LOCATION OF SITE: Talbotville

NAME OF COMPANY: CH2MHILL for confidential client

MEDIUM CONTAMINATED: soil, ground water

MAIN CONTAMINANTS: petroleum hydrocarbons

AT RISK: ground water supplies; private site cleanup

TECHNOLOGY USED: soil vapour extraction/carbon filtration

BRIEF DESC. OF TECHNOLOGY: ground water treatment and pumping to lower/control water table; contaminated soil excavated and replaced in the excavation for an engineered system of air stripping and vapour extraction; ground water treatment by activated carbon

TREATMENT RATE: not applicable

BEFORE/AFTER CONCENTRATIONS: soil; 5200 ppb toluene reduced to less than 700 ppb
ground water; 1170 ppb toluene reduced to non-detectable

DURATION OF REMEDIATION: approx. 1 year

APPROX. COST: not available

COMMENTS: free hydrocarbon on top of water table pumped out; heavily contaminated soil excavated and disposed of in landfill; soil vapour extraction system developed in excavation; final remediation was to Level II soil criteria of MOEE interim guideline for petroleum contaminated sites in Ontario; SOURCE OF INFORMATION: MOEE London Region files

CASE STUDY #5
SITE REMEDIATION TECHNOLOGY APPLICATION IN ONTARIO

LOCATION OF SITE: Port Stanley

NAME OF COMPANY: Sevenson/Waste Stream for client

MEDIUM CONTAMINATED: soil

MAIN CONTAMINANTS: oil tars, PAH, other organics

AT RISK: ground water, surface water, private remediation

TECHNOLOGY USED: ex-situ bioremediation

BRIEF DESC. OF TECHNOLOGY: enhanced bioremediation on 60mX120m clay-lined, bermed pad; collection and bio-treatment of surface water; treated water used to infiltrate into contaminated soil; soil treated with bacterial suspension and natural surfactants; daily tilling of soil; no winter operation; treated soil backfilled on site

TREATMENT RATE: not applicable

BEFORE/AFTER CONCENTRATIONS: variable; in excess of 1000 ppm TPH in soil reduced to less than 100 ppm TPH, and B(a)P in the 50 ppm range reduced to less than 10 ppm

DURATION OF REMEDIATION: started in 1989; on-going as of mid-1995

APPROX. COST: variable, depending on depth of soil excavation and concentration of contaminants; approx. $15 to $30 per tonne

COMMENTS: monitoring of surface water, ground water, air; 4700 cu. m. treated and 3365 cu. m. under treatment in 1993; soil treatment is by batch process, each batch being approximately 4000 cubic metres and lasting one to two months; each separate batch is sampled and must meet the total PAH criteria of 200 mg/kg criteria, and a B(a)P criteria of 10 mg/kg, both at the 95% sampling confidence level; in 1993, total PAH reductions varied from 93% to 96%, and B(a)P reductions were from 78% to 92%; SOURCE OF INFORMATION: MOEE London Region files

CASE STUDY #6
SITE REMEDIATION TECHNOLOGY APPLICATION IN ONTARIO

LOCATION OF SITE: Hamilton

NAME OF COMPANY: Groundwater Technology Canada Ltd. for client

MEDIUM CONTAMINATED: soil, ground water

MAIN CONTAMINANTS: petroleum hydrocarbons, chlorinated organic compounds, free product (xylene and mineral oil) on the water table

AT RISK: potential for ground water transport of volatile organics to residential basements in the area; vadose zone soil contamination; private site remediation project

TECHNOLOGY USED: soil vapour extraction (SVE), free product skimming and air sparging

BRIEF DESC. OF TECHNOLOGY: soil vapour extraction through 83 well points to a depth of 3 metres over an area of approximately 5000 m^2 three main header lines; free xylene skimming on top of the water table; carbon adsorption treatment of air before discharge; air sparging proposed to deal with ground water and enhance in-situ bioremediation; once sparging added, vapour treatment would be by on-site regenerable adsorption resin

TREATMENT RATE: on-going; more than 1000 kg of solvent recovered in 260 hours of operation

BEFORE/AFTER CONCENTRATIONS: BTEX in soils range up to 24,000 ppm and up to 16 ppm chlorinated organics; ground water contaminated with BTEX up to 114 ppm and with chlorinated organics up to 24.5 ppm; project still ongoing and cleanup levels not available

DURATION OF REMEDIATION: started November 1994 and ongoing as of Oct/95; site remediation projected to last 3 to 5 years

APPROX. COST: $20/tonne in-situ treated soil; project not yet complete; $450,000 capital and $50,000 - $100,000/year operating and maintenance for two years

COMMENTS: the contaminated area consists of two separate sources of contamination for petroleum hydrocarbons and chlorinated solvents; upper 3 metres of soil in vadose zone are contaminated with BTEX and oil and grease; zone between 6 and 9 metres in depth contains soil and ground water contaminated with chlorinated organics; 83 SVE wells at a flow rate of 60 scfm per well; 2-4000 lb carbon (per unit) treatment units for vapour treatment at 2400 scfm per unit; SOURCE OF INFORMATION: MOEE Hamilton Region office files and Paul Wilson of Groundwater Technology Canada Ltd. in Mississauga

CASE STUDY #7
SITE REMEDIATION TECHNOLOGY APPLICATION IN ONTARIO

LOCATION OF SITE: Breslau

NAME OF COMPANY: Groundwater Technology Canada Ltd. for client

MEDIUM CONTAMINATED: soil, ground water

MAIN CONTAMINANTS: historic releases of oil containing PCB, separate phase hydrocarbon (SPH) plume on top of water table

AT RISK: ground water, soil contamination; private remediation project

TECHNOLOGY USED: pilot scale steam injection to enhance mobility of oil and separate phase hydrocarbons; soil vapour extraction (SVE) to control steam propagation

BRIEF DESC. OF TECHNOLOGY: pilot scale system consisted of pumping of ground water to depress the water table and recover heated separate phase hydrocarbons (SPH), steam injection at 4 points around ground water depression cone; SPH heated to 100 degrees C to increase viscosity; SVE designed to control steam migration and breakout to atmosphere

TREATMENT RATE: not applicable; pilot scale study

BEFORE/AFTER CONCENTRATIONS: not applicable; pilot study to determine project parameters

DURATION OF REMEDIATION: 7 months

APPROX. COST: not applicable; pilot scale project

COMMENTS: a pilot scale project to determine the parameters necessary to recover the oil and separate phase hydrocarbons; one ground water pumping well 6.1 m deep, four steam injection wells 3.4 to 6.1 m deep, eight SVE wells 1.5 to 2.0 m deep; rate of steam injection at 120 kg/hr for 12 days; soil temperature maintained at 100 degrees C; difficulty in controlling steam breakthrough at surface; SOURCE OF INFORMATION: MOEE Hamilton Region office files and Paul Wilson of Groundwater Technlogy Canada Ltd. in Mississauga, Ontario

CASE STUDY #8
SITE REMEDIATION TECHNOLOGY APPLICATION IN ONTARIO

LOCATION OF SITE: Chemical production plant in eastern Ontario

NAME OF COMPANY: Laidlaw Waste Systems, Laidlaw Environmental Services for client

MEDIUM CONTAMINATED: surface soil

MAIN CONTAMINANTS: xylene

AT RISK: private site remediation in preparation for a new manufacturing facility

TECHNOLOGY USED: low temperature thermal desorption (LTTD)

BRIEF DESC. OF TECHNOLOGY: standard LTTD technology used to clean excavated soil and backfill on site; control of ground water to prevent recontamination

TREATMENT RATE: 20-30 tonnes/hour

BEFORE/AFTER CONCENTRATIONS: xylene reduced to less than 1.0 ppb; most cases non-detectable

DURATION OF REMEDIATION: 5 months

APPROX. COST: approximately $ 3 million; $85 per tonne

COMMENTS: 35,000 tonnes of soil processed; it is Laidlaw's opinion that the cost of mobilization of the LTTD unit makes it suitable for only medium to large remedial efforts, and that the contaminant must be suitable for this process, ie. volatile hydrocarbons in relatively low concentrations
SOURCE OF INFORMATION: R. Szudy/Rod Turnbull, Laidlaw Environmental Services Ltd., Central Region

CASE STUDY #9
SITE REMEDIATION TECHNOLOGY APPLICATION IN ONTARIO

LOCATION OF SITE: southwestern Ontario; confidential

NAME OF COMPANY: O'Connor Associates Environmental Inc. on behalf of a major of oil company

MEDIUM CONTAMINATED: limestone bedrock and ground water

MAIN CONTAMINANTS: various refined petroleum products (BTEX, TPH)

AT RISK: surrounding residential water wells

TECHNOLOGY USED: pump, treat and flush system

BRIEF DESC. OF TECHNOLOGY: ground water is recovered from peripheral wells, treated successively by coalescing filter, multi-media filter and enhanced oxidation (ultraviolet light and hydrogen peroxide) and injected into the bedrock near the spill site; excess water is discharged to a nearby stream

TREATMENT RATE: 70 L/min

BEFORE/AFTER CONCENTRATIONS: plant influent: 5 ppm TPH before, < 0.001 ppm after; ground water dissolved BTEX plume is shrinking

DURATION OF REMEDIATION: 3 years completed and 3 more years anticipated

APPROX. COST: $ 150,000 start-up and $ 70,000/year to operate

COMMENTS: ground water recovery and area of capture was enhanced by blast fracturing the bedrock; treated ground water is injected into a bedrock recharge zone to flush the residual hydrocarbons from the rock fractures; recovery/treatment system is fully automated with telephone/alarm link to office; completion of cleanup to be based on site-specific risk assessment and natural bio-attenuation of BTEX; SOURCE OF INFORMATION: Ronald McKee, O'Connor Assoc. Env. Inc. office in Oakville, Ontario

CASE STUDY #10
SITE REMEDIATION TECHNOLOGY APPLICATION IN ONTARIO

LOCATION OF SITE: south-central Ontario; confidential

NAME OF COMPANY: O'Connor Associates Environmental Inc. on behalf of a major chemical company

MEDIUM CONTAMINATED: soil (sand) and water table aquifer

MAIN CONTAMINANTS: fuel oil (BTEX, TPH)

AT RISK: building occupants, future land use

TECHNOLOGY USED: ex-situ bioremediation

BRIEF DESC. OF TECHNOLOGY: contaminated soil excavated and replaced in biocell constructed in the excavation; bioremediation enhanced through the addition of nutrients (fertilizer, water and oxygen) and the circulation of vapours derived from soil vapour extraction system in the cell

TREATMENT RATE: 500 m^3 soil in 6 months

BEFORE/AFTER CONCENTRATIONS: soil TPH was 6000 ppm to 16000 ppm before; < 100 ppm after

DURATION OF REMEDIATION: 2 summer seasons

APPROX. COST: approx. $25/tonne

COMMENTS: biocell is entirely below grade; no vapour emissions; respiration tests confirmed aerobic biodegradation occurring; SOURCE OF INFORMATION: Ronald McKee, O'Connor Assoc. Env. Inc. office in Oakville, Ontario

CASE STUDY #11
SITE REMEDIATION TECHNOLOGY APPLICATION IN ONTARIO

LOCATION OF SITE: southwestern Ontario; confidential

NAME OF COMPANY: O'Connor Associates Environmental Inc. on behalf of a major oil company

MEDIUM CONTAMINATED: soil (silt) and water table aquifer

MAIN CONTAMINANTS: various refined petroleum products (BTEX, TPH)

AT RISK: cultivated farm land and underlying bedrock aquifer

TECHNOLOGY USED: ex-situ bioremediation (land farming)

BRIEF DESC. OF TECHNOLOGY: contaminated soils are excavated, spread and tilled to permit volatilization, biodegradation and photo-oxidation of residual hydrocarbons, then used to backfill the excavation

TREATMENT RATE: 15,000 m^3 per 6 month season per year

BEFORE/AFTER CONCENTRATIONS: soil TPH 1000 ppm to 5000 ppm before, less than 100 ppm after

DURATION OF REMEDIATION: 5 years, completed and 1 more year anticipated

APPROX. COST: approximately $ 15/m^3

COMMENTS: treatability study indicated there was a sufficient supply of indigenous microbes and nutrients; SOURCE OF INFORMATION: Ronald McKee, O'Connor Assoc. Env. Inc. office in Oakville, Ontario

CASE STUDY #12
SITE REMEDIATION TECHNOLOGY APPLICATION IN ONTARIO

LOCATION OF SITE: south-central Ontario; confidential

NAME OF COMPANY: O'Connor Associates Environmental Inc. on behalf of a major oil company

MEDIUM CONTAMINATED: soil (sands) and ground water (water table aquifer)

MAIN CONTAMINANTS: gasoline (BTEX, TPH)

AT RISK: adjacent residence (hydrocarbon vapours) and surrounding water wells (dissolved BTEX)

TECHNOLOGY USED: ground water pump-and-treat and soil vapour extraction

BRIEF DESC. OF TECHNOLOGY: ground water pumped at a low rate from the dissolved plume and shipped for offsite recycling; pumping at a high rate conducted below the plume and the clean water discharged to a storm sewer without treatment; vapour extraction used to remove subsurface vapours and residual soil contamination

TREATMENT RATE: ground water: 60 L/min; vapour removal: 30 L/s

BEFORE/AFTER CONCENTRATIONS: maximum TPH concentration in ground water initially at 4.5 mg/L; TPH not detected at completion of remediation; soil vapour concentrations decreased from explosive levels to background levels

DURATION OF REMEDIATION: pump-and-treat: 4.5 years; vapour extraction: first 1.5 years

APPROX. COST: $150,000; unit costs not available

COMMENTS: used hydrogen peroxide to reduce iron bacterial fouling of pumping equipment; no vapour extraction offgas treatment necessary; SOURCE OF INFORMATION: Ronald McKee, O'Connor Assoc. Env. Inc. office in Oakville, Ontario

CASE STUDY #13
SITE REMEDIATION TECHNOLOGY APPLICATION IN ONTARIO

LOCATION OF SITE: south-central Ontario; confidential

NAME OF COMPANY: O'Connor Associates Environmental Inc. on behalf of a major oil company

MEDIUM CONTAMINATED: soil (sand fill) and water table aquifer

MAIN CONTAMINANTS: gasoline (BTEX, TPH)

AT RISK: on-site occupants and adjacent commercial properties

TECHNOLOGY USED: pump-and-treat and vapour extraction; bioslurping

BRIEF DESC. OF TECHNOLOGY: pump-and-treat system consists of liquid gasoline recovered by coalescing filter then recycled; decanted ground water is treated by municipal sewage treatment plant; hydrocarbons in collected vapours are destroyed by catalytic oxidation

TREATMENT RATE: ground water: 10 L/min; vapour removal: 150 L/s; approximately 1800 m^3 of soil within radius of influence of vapour extraction system

BEFORE/AFTER CONCENTRATION: recovered dissolved and vapour phase hydrocarbons are destroyed prior to release to the environment; average soil total BTEX concentrations were 165 ppm before vapour extraction and 15 ppm after 12 months

DURATION OF REMEDIATION: 12 months to date; not complete

APPROX. COST: $ 100,000/year operation costs; unit cost not available

COMMENTS: following removal of the most severe contamination by pump-and-treat and vapour extraction, the system has been replaced by a lower cost bioslurping system involving water skimming and bioventing; SOURCE OF INFORMATION: Ronald McKee, O'Connor Assoc. Env. Inc. office in Oakville, Ontario

CASE STUDY #14
SITE REMEDIATION TECHNOLOGY APPLICATION IN ONTARIO

LOCATION OF SITE: Mississauga

NAME OF COMPANY: former Wood Treating Facility

MEDIUM CONTAMINATED: upper 2 metres of soil

MAIN CONTAMINANTS: copper, chromium, arsenic

AT RISK: NA; private site remediation for redevelopment of the site

TECHNOLOGY USED: soil washing

BRIEF DESC. OF TECHNOLOGY: metal are recovered from soil in a pH adjusted water medium, the wash water is chemically treated to precipitate the metals, and the metal containing sludge is disposed at an approved facility. The treated, clean water is discharged into the sanitary sewer system.

TREATMENT RATE: not available

BEFORE/AFTER CONCENTRATIONS: * arsenic up to 2750 ppm reduced to less than 50 ppm;
* copper up to 1400 ppm reduced to less than 225 ppm;
* total chromium up to 795 ppm reduced to less than 725 ppm

DURATION OF REMEDIATION: approximately one year

APPROX. COST: not available

COMMENTS: the contamination originated from historic operation of the site as a wood treating facility; the cleanup was for the purpose of redevelopment of the site for industrial use; 18,000 cubic metres of soil, mainly gravel was processed; an additional 7,000 cubic metres of fine soil was processed but the arsenic criteria of 50 ppm could not be met and this soil was ultimately dispose of; confirmatory sampling of the soil is yet to be done as of July 1995; SOURCE OF INFORMATION: MOEE District office files in Oakville

CASE STUDY #15
SITE REMEDIATION TECHNOLOGY APPLICATION IN ONTARIO

LOCATION OF SITE: Mississauga

NAME OF COMPANY: Petro-Canada

MEDIUM CONTAMINATED: soil

MAIN CONTAMINANTS: petroleum hydrocarbons (BTEX)

AT RISK: the site is a facility to bioremediate imported soil from Petro-Canada service stations

TECHNOLOGY USED: ex-situ bioremediation

BRIEF DESC. OF TECHNOLOGY: the site consists of five engineered bioremediation cells, 2,000 tonnes each; each cell is 0.5 m below grade and approximately 10.5 above site grade; each cell is line with plastic liner, and contains drainage/collection lines to collect porewater, free product, and petroleum hydrocarbon vapour; each cell is covered by a "solar blanket" to limit release of fugitive emissions; soil treatment consists of soil tilling and the addition of nutrients; water and vapours are treated before discharge

TREATMENT RATE: approximately 4 weeks per cell

BEFORE/AFTER CONCENTRATIONS: hydrocarbon contaminated soil reduced to meet MOEE guidelines for BTEX and total petroleum hydrocarbons

DURATION OF REMEDIATION: this is a permanent site to treat imported soil from individual sites contaminated with petroleum hydrocarbons

APPROX. COST: $25 to $30/tonne (includes transportation)

COMMENTS: contaminated soil from Petro-Canada service stations are brought to this site for treatment, and clean soil is returned to the excavation sites; vapours are treated through a biofilter consisting of vegetative organic matter contained within a pressurized metal treatment vessel; vapours and water are monitored before discharge; SOURCE OF INFORMATION: file information provided by F. Seif, Petro-Canada Products, North York, Ontario.

CASE STUDY #16
SITE REMEDIATION TECHNOLOGY APPLICATION IN ONTARIO

LOCATION OF SITE: Cornwall

NAME OF COMPANY: Proctor & Redfern Limited for client

MEDIUM CONTAMINATED: soil, ground water

MAIN CONTAMINANTS: petroleum hydrocarbons, xylene

AT RISK: private site cleanup to prevent off-site migration of contaminated ground water

TECHNOLOGY USED: low temperature thermal desorption (LTTD)

BRIEF DESC. OF TECHNOLOGY: normal LTTD technology; contaminated soil heated in a mobile rotary kiln to volatilize contaminants, followed by the destruction of volatile components in a secondary combustion unit

TREATMENT RATE: approximately 30 tonnes/hr

BEFORE/AFTER CONCENTRATIONS: BTEX; maximum concentration of 15,000 ppm reduced to less than 5 ppm

DURATION OF REMEDIATION: 3.5 months

APPROX. COST: $2.5 million total; $47/tonne (includes excavation)

COMMENTS: the contamination was the result of historic industrial operations on the site, and the cleanup was a private site remediation project to prevent the contamination of ground water; although xylene contaminated soils were treated, it was also possible to treat heavier petroleum contaminated soil; SOURCE OF INFORMATION: D. White, Proctor & Redfern Ltd. files in Hamilton

CASE STUDY #17
SITE REMEDIATION TECHNOLOGY APPLICATION IN ONTARIO

LOCATION OF SITE: Toronto

NAME OF COMPANY: Gartner Lee Ltd. on behalf of client

MEDIUM CONTAMINATED: ground water

MAIN CONTAMINANTS: mineral oil, PCB

AT RISK: ground water infiltration into basement of adjacent property

TECHNOLOGY USED: product recovery, filtration of oil from ground water

BRIEF DESC. OF TECHNOLOGY: ground water recovery wells on subject property and pumps installed in basement of adjacent property to collet contaminated ground water; ground water pumped through fabric filter with affinity for oil prior to discharge into sanitary sewer;

TREATMENT RATE: intermittent, as ground water accumulated in basement

BEFORE/AFTER CONCENTRATIONS: treatment of ground water to below sewer use by-law limit of 15 mg/l oil and grease; PCBs not detected in ground water

DURATION OF REMEDIATION: started in 1990; ongoing in 1995

APPROX. COST: $100,000; unit cost not available

COMMENTS: SOURCE OF INFORMATION: Steven Gable, Gartner Lee Limited in Markham, Ontario

CASE STUDY #18
SITE REMEDIATION TECHNOLOGY APPLICATION IN ONTARIO

LOCATION OF SITE: 21 sites in Ontario

NAME OF COMPANY: Imperial Oil Limited

MEDIUM CONTAMINATED: unsaturated soil

MAIN CONTAMINANTS: petroleum hydrocarbons; BTEX

AT RISK: ground water, air; private soil cleanups

TECHNOLOGY USED: soil vapour extraction/carbon filtration and catalytic converter system

BRIEF DESC. OF TECHNOLOGY: 2.5" PVC screened and slotted vertical pipes in the unsaturated soil and connected to a common header which is connected to a suction pump in line with activated carbon filled drums or a catalytic converter system

TREATMENT RATE: variable;

BEFORE/AFTER CONCENTRATIONS: soil not sampled routinely; soil treatment considered complete when gasoline vapours (BTEX) from contaminated soil reduced to less than 200 ppm BTEX

DURATION OF REMEDIATION: 3 to 18 months

APPROX. COST: $50,000 to $100,000 per service station site, depending on the site conditions

COMMENTS: the technology is applied at operating service station sites and at sites where off-site impacts need addressing; the systems work well in sandy to silty soil, and do not work in clay or where water table is shallow; carbon filters are used where small volumes/rates of VOCs need treatment; catalytic converter is used where large volumes/raters of VOCs are produced; SOURCE OF INFORMATION: Z. Hasan of Imperial Oil Ltd. in Don Mills

CASE STUDY # 19
SITE REMEDIATION TECHNOLOGY APPLICATION IN ONTARIO

LOCATION OF SITE: 4 sites in Ontario

NAME OF COMPANY: Imperial Oil Ltd./Barenco Inc.

MEDIUM CONTAMINATED: soil

MAIN CONTAMINANTS: petroleum hydrocarbons/BTEX

AT RISK: ground water; private cleanups

TECHNOLOGY USED: ex-situ, natural bioremediation

BRIEF DESC. OF TECHNOLOGY: petroleum hydrocarbon contaminated soil is enriched with nutrients (fertilizer) and placed in piles covered with plastic sheets; 4" perforated piping installed to supply air as required; mobile air pumping system is used to provide further oxygen enrichment as required

TREATMENT RATE: NA

BEFORE/AFTER CONCENTRATIONS: before: up to 25,000 ppm TPH in soil
after: less than 100 ppm TPH in soil

DURATION OF REMEDIATION: 6 to 24 months

APPROX. COST: $ 25 to $50 per cubic metre, depending on site conditions and the concentration of the contaminants

COMMENTS: the technology is applied mainly to degrade residual gasoline and diesel fuel contaminated soil (no free product) at non-operation service station sites; works well in sandy to clayey soils; air is pumped in through 4" piping approximately every 2 months; SOURCE OF INFORMATION: Z. Hasan of Imperial Oil Ltd. in Don Mills and J. Phimister of Barenco

CASE STUDY # 20
SITE REMEDIATION TECHNOLOGY APPLICATION IN ONTARIO

LOCATION OF SITE: Smithville

NAME OF COMPANY: for MOEE

MEDIUM CONTAMINATED: soil, ground water

MAIN CONTAMINANTS: waste oil containing PCB and other organics

AT RISK: public health, ground water

TECHNOLOGY USED: high temperature incineration of contaminated soil; pumping and treatment of contaminated ground water to contain the spread of contamination

BRIEF DESC. OF TECHNOLOGY: the treatment of contaminated soil involved standard kiln technology to destroy PCB-contaminated solids, liquids, sludges and the treatment of contaminated soil; to control the migration of contaminated ground water, the water is pumped to the surface and treated chemically before discharge to the local sanitary sewer; research is ongoing to determine cleanup technologies to applicable for the cleanup of limestone bedrock contaminated by the waste oil containing PCBs

TREATMENT RATE: average: 30 tonnes/day; up to 100 tonnes/day

BEFORE/AFTER CONCENTRATIONS: no detectable contaminants levels in treated soil; ground water remediation not yet started

DURATION OF REMEDIATION: soil cleanup lasted less than one year; ground water control measures on-going as of 1995 and expected to last another 5 years while research is being conducted to determine ways of removing contaminants from limestone bedrock;

APPROX. COST: $22.48 million; $2737/$m^3$

COMMENTS: 8213m^3 of contaminated soil treated, plus other contaminated materials such as transformers; the site was a transfer station for PCB-laden waste oil and contained other hazardous waste that discharged into the ground as the result of poor housekeeping on the site; soil and ground water was contaminated; limestone bedrock is shallow and contains the waste from the site; the local municipal ground water source was switched to a surface water source supplying Grimsby; the site contains a permanent water treatment facility for ground and surface water; SOURCE OF INFORMATION: MOEE Regional office in files Hamilton

CASE STUDY # 21
SITE REMEDIATION TECHNOLOGY APPLICATION IN ONTARIO

LOCATION OF SITE: Rednersville

NAME OF COMPANY: Ministry of Environment and Energy

MEDIUM CONTAMINATED: ground water, soil

MAIN CONTAMINANTS: trichloroethylene, vinyl chloride

AT RISK: domestic ground water supplies

TECHNOLOGY USED: ground water pump and treat and natural flushing of ground water

BRIEF DESC. OF TECHNOLOGY: contaminated soil has been excavated and disposed of; ground water is treated by point-of-use carbon treatment systems on residential water supply systems; treatment consists of downhole hydrogen peroxide pretreatment, followed by granular activated carbon filter connected in series and ultraviolet lamp;

TREATMENT RATE: 4/5 gallons per minute

BEFORE/AFTER CONCENTRATIONS: TCE concentration up to 320 ppb reduced to non-detectable at point of use; TCE concentration in the ground water contamination plume are slowly decreasing

DURATION OF REMEDIATION: ground water treatment started in 1988; on-going as of August 1995; expect another 2 to 3 years before natural flushing will reduce contaminant level to acceptable concentrations

APPROX. COST: $1 million; per unit cost not available

COMMENTS: contamination originated from an illegal dumping of industrial waste; ground water contamination is being flushed through by natural infiltration of precipitation and by domestic pumping of wells; the TCE and cis-1-,2-DCE, a transformation product of TCE, contaminant plume is weakening in some areas and increasing in strength in other areas as it moves downgradient in the direction of ground water flow; SOURCE OF INFORMATION: MOEE District office file in Belleville

CASE STUDY # 22
SITE REMEDIATION TECHNOLOGY APPLICATION IN ONTARIO

LOCATION OF SITE: 9 site locations in Ontario

NAME OF COMPANY: Arcturus Environmental on behalf of clients

MEDIUM CONTAMINATED: ground water

MAIN CONTAMINANTS: petroleum hydrocarbons (gasoline/diesel fuel)

AT RISK: ground water

TECHNOLOGY USED: granular activated carbon

BRIEF DESC. OF TECHNOLOGY: ground water is pumped from on-site recovery wells to an oil/water separator where free-phase petroleum product is separated from the contaminated ground water; the water is passed through a sand filter and then through a granular activated carbon treatment cell; the treated water is discharged to a sanitary sewer;

TREATMENT RATE: variable; 10 to 20 gallons per minute, depending on concentration of contaminants and ground water pumping rate

BEFORE/AFTER CONCENTRATIONS: concentrations up to 1000 ppm TPH in ground water reduced to 10 ppm

DURATION OF REMEDIATION: variable project durations from months to years

APPROX. COST: $0.01/litre to $0.25/litre

COMMENTS: the treatment of ground waters constitute only part of the site remediation project from which the above information has been summarized; these treatments often accompany soil remediation by treatment technologies appropriate for the situation;
SOURCE OF INFORMATION: A. Maddalena of Arcturus Environmental in Niagara Falls, Ontario

CASE STUDY # 23
SITE REMEDIATION TECHNOLOGY APPLICATION IN ONTARIO

LOCATION OF SITE: 11 site locations in Ontario

NAME OF COMPANY: Arcturus Environmental on behalf of clients

MEDIUM CONTAMINATED: soil

MAIN CONTAMINANTS: petroleum hydrocarbons (gasoline/diesel fuel)

AT RISK: ground water; private site remediation projects

TECHNOLOGY USED: ex-situ, natural bioremediation

BRIEF DESC. OF TECHNOLOGY: contaminated soil is excavated and placed in a biological treatment area that is lined with HDPE to prevent the migration of any contaminated pore water; nutrients are added, usually monthly, to the soil and augmented by the application of water-soluble fertilizer that is mixed into the soil; pore water is collected from the treatment area and treated in an on-site granular activated carbon treatment system;

TREATMENT RATE: NA

BEFORE/AFTER CONCENTRATIONS: TPH concentrations in soil up to 30,000 ppm are reduced to below 50 ppm

DURATION OF REMEDIATION: usually between 60 and 90 days

APPROX. COST: $2/tonne to $33/tonne, depending on the complexity of the site remediation project

COMMENTS: the ex-situ bioremediation treatment of soil may be part of a total site remediation project that includes the treatment of contaminated ground water; the technology is most effective in the summer months; SOURCE OF INFORMATION: A. Maddalena of Arcturus Environmental in Niagara Falls, Ontario

CASE STUDY # 24
SITE REMEDIATION TECHNOLOGY APPLICATION IN ONTARIO

LOCATION OF SITE: Hamilton

NAME OF COMPANY: Jacques Whitford Environment Ltd. for client

MEDIUM CONTAMINATED: soil, ground water

MAIN CONTAMINANTS: petroleum hydrocarbons (BTEX)

AT RISK: petroleum vapours in manholes, catch basins

TECHNOLOGY USED: soil vapour extraction (SVE)

BRIEF DESC. OF TECHNOLOGY: water table was lowered to recover free-phase hydrocarbons and allow vapour extraction in unsaturated zone; ground water was treated by activated carbon before discharge to sanitary sewer; vapours were treated through a catalytic vapour treatment module

TREATMENT RATE: 2340 litres of liquid hydrocarbons removed by SVE from unsaturated zone and treated over 8 months

BEFORE/AFTER CONCENTRATIONS: up to 6700 ppm TPH still remaining in the soil locally

DURATION OF REMEDIATION: approximately 8 months

APPROX. COST: not available

COMMENTS: the SVE was not effective in the removal of BTEX contamination from soil in the saturated zone below MOEE Level III criteria; because of a continued source of hydrocarbons on the water table, it is not possible to determine the effectiveness of the SVE in the cleanup of the contaminated unsaturated soil, although vapour levels have been decreased and it is claimed that the SVE process was effective in the cleanup of the unsaturated soil; up to 22 mm of floating hydrocarbon was detected on the water table;
SOURCE OF INFORMATION: MOEE Hamilton Region office files

APPENDIX B: CASE STUDIES IN OTHER JURISDICTIONS

NOTE: the case study sheets contain a mix of metric and English units as provided by the respondents; to maintain integrity and accuracy of the information as provided by the respondents, no attempt has been made to change to one set of units

CASE STUDY #25
SITE REMEDIATION TECHNOLOGY APPLICATION IN QUEBEC

LOCATION OF SITE: Montreal, P.Q.

NAME OF COMPANY: Groundwater Technology Inc. for Shell Canada

MEDIUM CONTAMINATED: soil

MAIN CONTAMINANTS: petroleum hydrocarbons

AT RISK: Shell Canada Products Ltd. site remediation

TECHNOLOGY USED: ex-situ bioremediation

BRIEF DESC. OF TECHNOLOGY: 2 treatment cells on cement pads; capacity of each cell = 1200 cu m of soil; venting systems for aeration of contaminated soils; soil conditioning by addition of gypsum, mixing, addition of natural filler to increase soil permeability, and addition of nutrients;

TREATMENT RATE: not applicable

BEFORE/AFTER CONCENTRATIONS: before: 6500 mg/kg total petroleum hydrocarbons
after 10 months: 790 mg/kg TPH

DURATION OF REMEDIATION: 12 months

APPROX. COST: not available

COMMENTS: 3000 cu m contaminated soil; low permeability clay soil of concern; treatment progressed during winter months; a permanent facility to treat contaminated soil at the facility
REFERENCE: "Bioremediation Treats Contaminated Soils in Canadian Winter"; Oil & Gas Journal, Nov. 2, 1992.

CASE STUDY #26
SITE REMEDIATION TECHNOLOGY APPLICATION IN USA

LOCATION OF SITE: Catasauqua, Pa

NAME OF COMPANY: Groundwater Technology Inc. for client

MEDIUM CONTAMINATED: soil, ground water

MAIN CONTAMINANTS: 940 gallons of leaded gasoline; hydrocarbons

AT RISK: communal water supply well

TECHNOLOGY USED: combination of recovery wells, air stripping, in-situ bioremediation

BRIEF DESC. OF TECHNOLOGY: recovery wells pumped contaminated water to air stripper, and clean water was returned to ground through infiltration gallery; in-situ bioremediation involved addition of hydrogen peroxide and a nutrient mixture of organic elements to remediate the contaminated soil

TREATMENT RATE: not applicable

BEFORE/AFTER CONCENTRATIONS: NA; claim 99% reduction in contaminants to 1 ppb total hydrocarbons in the recovery wells

DURATION OF REMEDIATION: 18 months

APPROX. COST: not available

COMMENTS: claim bioremediation to be faster in this case than pump/treat and air stripping alone;
REFERENCE: "Bioremediation Saves Groundwater Supply" in PUBLIC WORKS publication of Indiana, May 1988

CASE STUDY #27
SITE REMEDIATION TECHNOLOGY APPLICATION IN USA

LOCATION OF SITE: Pine Barrens, NJ

NAME OF COMPANY: Groundwater Technology Inc. for client

MEDIUM CONTAMINATED: soil, ground water

MAIN CONTAMINANTS: unleaded gasoline; hydrocarbons

AT RISK: ground water; fire, explosion hazard due to spill

TECHNOLOGY USED: on-site ground water extraction and treatment; soil vapour extraction and bioremediation

BRIEF DESC. OF TECHNOLOGY: extracted ground water treated by air stripping; this effluent was mixed with nutrients and hydrogen peroxide, and reinjected into vadose zone to accelerate in-situ bioremediation of adsorbed contaminants; soil vapour extraction applied to pile of excavated soil on surface and contaminated soil in the vadose zone; catalytic oxidation of air emissions

TREATMENT RATE: 35 gallons of gasoline per month by air stripping;
3 gallons of gasoline per day by soil vapour extraction

BEFORE/AFTER CONCENTRATIONS: not available

DURATION OF REMEDIATION: not available

APPROX. COST: US$600K - US$800K

COMMENTS: 6800 cu yards of contaminated soil in vadose zone; only small amount of spill reached the water table; REFERENCE: " GTI Project Profile: Southeastern New Jersey Fuel Distribution Facility, May 1992";

CASE STUDY #28
SITE REMEDIATION TECHNOLOGY APPLICATION IN USA

LOCATION OF SITE: Houston, Texas

NAME OF COMPANY: Groundwater Technology for client

MEDIUM CONTAMINATED: soil

MAIN CONTAMINANTS: petroleum hydrocarbons

AT RISK: private site cleanup

TECHNOLOGY USED: thermal desorption, air sparging, bioremediation and aeration of contaminated ground water

BRIEF DESC. OF TECHNOLOGY: on-site thermal desorption of 27,000 tons of excavated contaminated soil; contaminated ground water recovery and treatment by air sparging and in-situ bioremediation; biodegradation and aeration of contaminated ground water seeping into excavation;

TREATMENT RATE: thermal desorption of 500 tons per day (max)

BEFORE/AFTER CONCENTRATIONS: not available

DURATION OF REMEDIATION: not available

APPROX. COST: not available

COMMENTS: 27,000 tons of contaminated soil; REFERENCE: "GTI Project Profile: Texas Water Commission Eastex Freeway Site, April 1992"

CASE STUDY #29
SITE REMEDIATION TECHNOLOGY APPLICATION IN USA

LOCATION OF SITE: Quincy, Mass.

NAME OF COMPANY: Groundwater Technology Inc. for client

MEDIUM CONTAMINATED: ground water

MAIN CONTAMINANTS: #2 fuel oil; hydrocarbons

AT RISK: river water

TECHNOLOGY USED: liquid-phase recovery of petroleum; air stripper to treat ground water;

BRIEF DESC. OF TECHNOLOGY: lower water table with 7 wells to create hydraulic trap; pump contaminated liquid with oil/water separator system; treat contaminated ground water through air stripper tower and discharge to the river

TREATMENT RATE: variable; 100,000 gallons in first month of operation; 410,500 gallons recovered between 1986 and 1993

BEFORE/AFTER CONCENTRATIONS: not available; up to 11 feet of liquid-phase fuel oil reduced to 2 inches

DURATION OF REMEDIATION: 6+ years

APPROX. COST: not available

COMMENTS: 600,000 gallons of leaked fuel oil; up to 11 feet of liquid-phase petroleum; oil/water separator achieved virtually 100% water-free product recovery that was reused as heating oil;
REFERENCE: " GTI Project Profile: QQuincy, Massachusets Shipbuilding Facility, Oct. 1993"

CASE STUDY #30
SITE REMEDIATION TECHNOLOGY APPLICATION IN USA

LOCATION OF SITE: Denver, Colorado

NAME OF COMPANY: Groundwater Technology Inc. for client

MEDIUM CONTAMINATED: soil, ground water

MAIN CONTAMINANTS: used motor oil; hydrocarbons

AT RISK: private site cleanup

TECHNOLOGY USED: in-situ bioremediation; vapour extraction

BRIEF DESC. OF TECHNOLOGY: in-situ bioremediation used indigenous bacteria stimulated with additions of atmospheric oxygen and inorganic nutrients; contaminated ground water treated with carbon adsorption and returned to aquifer after additions of nutrient and hydrogen peroxide; vadose zone contamination addressed using nutrient infiltration points with vapour extraction;

TREATMENT RATE: not applicable

BEFORE/AFTER CONCENTRATIONS: 420 mg/kg BTEX, 5200 mg/kg TPH as gasoline, 12,000 mg/kg total oil and grease in soil; after two years, BTEX = ND, TPH = 55 mg/kg, total oil/grease = 1900 mg/kg in soil;

DURATION OF REMEDIATION: 3 years

APPROX. COST: not available

COMMENTS: 26,400 lb. of hydrocarbons in ground water and soil, plus separate-phase oil; 35,590 lb. of contaminants removed by bioremediation; 4% by separate-phase recovery, 2% by vapour extraction, and 94% by bioremediation; 9,000,000 gallons of ground water treated and reinjected; REFERENCE; "GTI Project Profile: Public Service Company of Colorado Fleet Maintenance Facility, Jan. 1994"

CASE STUDY #31
SITE REMEDIATION TECHNOLOGY APPLICATION IN USA

LOCATION OF SITE: Bakersfield, California

NAME OF COMPANY: TreaTek-CRA Company for client

MEDIUM CONTAMINATED: soil

MAIN CONTAMINANTS: gasoline, diesel fuel

AT RISK: private spill cleanup required by California law

TECHNOLOGY USED: in-situ soil vapour extraction

BRIEF DESC. OF TECHNOLOGY: three sets of cluster wells 45 feet deep; catalytic oxidation treatment of vapour

TREATMENT RATE: not applicable

BEFORE/AFTER CONCENTRATIONS (soil):

sample depth (ft)	BTEX (ppm)	BTEX (ppm)
10	650	less than 1
20	2700	"
30	440	"
40	880	"
50	1100	"

DURATION OF REMEDIATION: 18 months

APPROX. COST: $US180,000

COMMENTS: site contaminated by leaking storage tanks; not a direct hazard to ground water or the environment, but California law requires cleanup; client was a major railroad company on the west coast; SOURCE OF INFORMATION: Antony Ying, TreaTek - CRA Company in Niagara Falls, NY

CASE STUDY #32
SITE REMEDIATION TECHNOLOGY APPLICATION IN USA

LOCATION OF SITE: Gang Mills, New York

NAME OF COMPANY: TreaTek-CRA Company for major fuel distribution company in the USA

MEDIUM CONTAMINATED: soil, ground water

MAIN CONTAMINANTS: gasoline (petroleum hydrocarbons)

AT RISK: ground water contamination; private site cleanup

TECHNOLOGY USED: in-situ bioremediation, soil vapour extraction and air sparging

BRIEF DESC. OF TECHNOLOGY: application of nutrients and microorganisms (in liquid slurry) below the water table, and air sparging to remove volatile organics from ground water and contaminated soil in the saturated zone; soil vapour extraction to remove volatile organics from soil in the unsaturated zone

TREATMENT RATE: not applicable

BEFORE/AFTER CONCENTRATIONS: (in ground water)

- Benzene levels up to 1100 ppb reduced to non-detectable
- Ethylbenzene levels up to 1200 ppb reduced to non-detectable
- Toluene levels up to 23000 ppb reduced to non-detectable
- Xylene levels up to 4000 ppb reduced to non-detectable
- MTBE (a gasoline additive) levels up to 120 ppb reduced to non-detectable

DURATION OF REMEDIATION: 12 months

APPROX. COST: $US50,000

COMMENTS: the site is a bulk storage terminal contaminated by petroleum hydrocarbons; the State of New York allows the monitoring of ground water as an indicator of the degree of cleanup of soil in which the contamination occurs; no sampling of soil is necessary if ground water is sampled;
SOURCE OF INFORMATION: Antony Ying, TreaTek - CRA Company in Niagara Falls, NY

CASE STUDY #33
SITE REMEDIATION TECHNOLOGY APPLICATION IN USA

LOCATION OF SITE: Long Island, New York

NAME OF COMPANY: TreaTek-CRA Company for local power plant in New York

MEDIUM CONTAMINATED: unsaturated soil, ground water

MAIN CONTAMINANTS: diesel fuel

AT RISK: ground water contamination; private site remediation

TECHNOLOGY USED: in-situ bioremediation, soil vapour extraction, air injection

BRIEF DESC. OF TECHNOLOGY: application of nutrients to surface soils through infiltration gallery, air injection and soil vapour extraction through wells

TREATMENT RATE: not applicable

BEFORE/AFTER CONCENTRATIONS (in ground water):

Benzene at 10 ppb reduced to less than 1 ppb after 12 months
Toluene at 28 ppb reduced to less than 1 ppb after 12 months
Ethylbenzene at 131 ppb reduced to less than 1 ppb after 12 months
Xylene at 487 ppb reduced to less than 1 ppb after 12 months
TPH greater than 1000 ppb reduced to less than 0.4 ppb after 12 months
Naphthalene greater than 150 ppb reduced to less than 10 ppb
Phenanthrene greater than 150 ppb reduced to less than 50 ppb

DURATION OF REMEDIATION: 22 months

APPROX. COST: $US250,000

COMMENTS: one of the earliest in-situ bioremediation projects in the State of New York; client is a municipality (local town power plant) in Long Island; soil sampling in not required in New York State as long as ground water is sampled and analyzed for contaminants; this assumes that if the contaminants are not found in ground water, the source of contaminants in the unsaturate soil have been cleaned up; SOURCE OF INFORMATION: Antony Ying, TreaTek-CRA Company in Niagara Fall, NY

CASE STUDY #34
SITE REMEDIATION TECHNOLOGY APPLICATION IN USA

LOCATION OF SITE: Niagara Falls, New York

NAME OF COMPANY: TreaTek-CRA Company for US Air Force

MEDIUM CONTAMINATED: unsaturated soil

MAIN CONTAMINANTS: gasoline and jet fuel

AT RISK: ground water contamination; private site cleanup

TECHNOLOGY USED: in-situ bioremediation and air injection

BRIEF DESC. OF TECHNOLOGY: application of nutrients and microorganisms through infiltration gallery into unsaturated soil; air injection through well points

TREATMENT RATE: not applicable

BEFORE/AFTER CONCENTRATIONS: (TCLP* results in ppb)

Benzene up to 440 ppb reduced to less than 0.2 ppb
Ethyl benzene up to 65 ppb reduced to less than 0.2 ppb
Toluene up to 75 ppb reduced to less than 0.2 ppb
Xylene up to 830 ppb reduced to less than 0.2 ppb
Napthalene up to 66 ppb reduced to less than 0.6 ppb

DURATION OF REMEDIATION: 8 months

APPROX. COST: $US280,000

COMMENTS: * TCLP tests represent leachate tests on soil; direct soil ananlyses not necessary;
SOURCE OF INFORMATION: Antony Ying, TreaTek-CRA Company in Niagara Falls, New York

CASE STUDY # 35
SITE REMEDIATION TECHNOLOGY APPLICATION IN MANITOBA

LOCATION OF SITE: The Pas, Manitoba

NAME OF COMPANY: Groundwater Technology Canada Ltd. and Manitoba Hazardous Waste Management Corp.

MEDIUM CONTAMINATED: soil

MAIN CONTAMINANTS: bunker C (heavy end hydrocarbons, oil, grease)

AT RISK: NA; private site remediation leading to land transfer

TECHNOLOGY USED: ex-situ bioremediation (fungal treatment in engineered biocell)

BRIEF DESC. OF TECHNOLOGY: vapour extraction enhanced biological treatment cells with nutrient and water addition capabilities; separate fungal cell augmented with white rot fungus and progress monitored using (fungal) gene probe technology

TREATMENT RATE: treatment expected within 18 months of startup in fall of 1995

BEFORE/AFTER CONCENTRATIONS: 10 - 15,000 ppm mineral oil and grease treated to closure criteria of less than 800 ppm

DURATION OF REMEDIATION: 18 months

APPROX. COST: approximately $60/tonne

COMMENTS: approximately 10,000 tonnes of contaminated sandy, silty, clayey fill material; SOURCE OF INFORMATION: Paul Wilson of Groundwater Technology Canada Ltd. in Mississauga, Ontario

APPENDIX C: NCSRP CASE STUDIES OF EMERGING TECHNOLOGIES

NOTE: some NCSRP projects are on-going as of September 1995 and the project summary sheets are current as of this date

The National Contaminated Sites Remediation Program

DESRT Development and Demonstration of Site Remediation Technology

DARAMEND™ BIOREMEDIATION OF SOILS CONTAINING CHLOROPHENOLS AND POLYNUCLEAR AROMATIC HYDROCARBONS (FULL-SCALE DEMONSTRATION)

Grace Dearborn Inc., Mississauga, Ontario
-Project Summary-

May 1995 (Final Update)

INTRODUCTION

In 1989, the Canadian Council of Ministers of the Environment (CCME) established the National Contaminated Sites Remediation Program (NCSRP), which is supported and administered through federal-provincial-territorial bilateral agreements.

The DESRT (Development and Demonstration of Site Remediation Technology) program was established to address the NCSRP objective of working with Industry to stimulate the development and demonstration of new and innovative technologies having the potential to resolve problems which are critical to the environmental remediation of contaminated sites.

TECHNOLOGY DESCRIPTION

The Daramend™ Bioremediation Technology was developed by Grace Dearborn Inc. in coordination with Environment Canada. This technology, which involves the use of solid phase organic amendments of specific particle size, nutrient profile, and nutrient release kinetics, was used to treat soils containing chlorophenols (CPs), particularly pentachlorophenol (PCP), and polynuclear aromatic hydrocarbons (PAHs).

Two other Technical Summary sheets are available, within the DESRT series, which describe the pilot-scale phases of the work (dated December 1993 & June 1994).

DESRT SUPPORTED TECHNOLOGY

Previous pilot-scale demonstrations, completed in June 1994, of this technology were supported in part by the DESRT program ($746,650). Funding for the full-scale demonstration of this technology was provided by the Metro Toronto Region Conservation Authority (MTRCA) as well as the Ontario Ministry of Environment and Energy (MOEE) and Environment Canada under the joint federal and provincial DESRT funding program. The total cost for the project was $741,000 and the DESRT contribution was $370,500.

SITE HISTORY

The industrial site chosen for the full-scale demonstration of the Daramend™ technology was a wood preserving site which is currently used only for the storage of treated wood. Previously, treatment of wood poles at the site utilized both creosote and PCP as preservatives. Further details on the site can be found on Technical Summary Sheets detailing the pilot-scale work.

TECHNOLOGY DEMONSTRATION SUMMARY

This demonstration was conducted from the summer of 1993 to the summer of 1994. Field work involved the full scale demonstration of the technology, in both in-situ and ex-situ conditions. A laboratory bench-scale in-parallel microcosm study was set up to verify the results of the ex-situ field work.

In-situ demonstration

The **in-situ demonstration** was designed to treat an area of the site approximately 4,800 m^2 in size to a depth of 0.6 m. This constituted approximately 3,500 tonnes of soil. The 4,800 m^2 was divided into 49 separate sampling areas of approximately 100 m^2 each.

Daramend product D6380 was applied to the soil at a rate determined by the pre-treatment target compound concentrations and the physical and chemical properties of the soil. Results from both bench-scale and pilot-scale work at the site were evaluated in the selection of the amendment. The required mass of product was placed on the soil surface and incorporated to a depth of 0.6 m with a specialized tractor-mounted rotary tiller.

The in-situ demonstration area was tilled twice monthly to ensure continued uniformity of treatment with depth and to aerate the soil matrix. No tillage was performed in January, February or March of 1994. Irrigation was not required because adequate precipitation maintained an acceptable soil moisture content.

Ex-situ demonstration

During the **ex-situ demonstration**, approximately 1,500 tonnes of excavated soil was treated using Daramend bioremediation in two fully contained treatment cells. Each treatment cell was designed to accommodate approximately 750 tonnes of soil and was composed of a high density polyethylene (HDPE) liner over a layer of woven geotextile, underlain by clay and surrounded by a clay berm. The HDPE liner covered both the base of each treatment cell and the walls of the clay berms. A 15 cm layer of sand separated the soil from the HDPE liner in each treatment cell. Both treatment cells were covered with steel/polyethylene greenhouses to permit continuation of treatment through the winter months. Size limitations necessitated the construction of two treatment cells.

Daramend products D6380 and D6399 were applied to the soils at rates determined by the pre-treatment target compound concentrations and by a process optimization bench-scale parallel microcosm study. Results from previous bench-scale optimization studies and pilot-scale work were also evaluated for selection of amendments.

Soil in the ex-situ treatment cells was tilled once a week to ensure continued uniformity of treatment with depth and to aerate the soil matrix. No tillage was performed in February or March of 1994 when soils in the treatment cells were frozen. Irrigation was performed, with detailed monitoring to ensure an acceptable soil moisture content was maintained.

A portion of the ex-situ Treatment Cell 2 demonstration was monitored by the US EPA under the SITE demonstration program.

DEMONSTRATION RESULTS

The influence of Daramend bioremediation on the CP and PAH concentrations in both the in-situ and ex-situ demonstration area soils was monitored through successive sampling events. The in-situ demonstration area was divided into 49 sampling areas while the ex-situ Treatment Cells 1 and 2 were divided into 13 and 10 sampling areas, respectively. These sampling areas were subsequently subdivided into 1 m x 1 m pedons. At each sampling period, several randomly selected pedons per sampling area were chosen and these soils were homogenized in order to give one sample per area. All analyses were done by an independent lab, the Wastewater Technology Centre

Initially, in the in-situ demonstration area, there were 17 (of 49) zones which were above CCME criteria of 5 mg CP/kg and 10 (of 49) which exceeded the PAH criteria levels.

For Treatment Cell 1, the initial average total chlorophenol concentration was 157 mg/kg and the initial average total PAH concentration was 439 mg/kg. Treatment Cell 2 had an average initial total PAH concentration of 619 mg/kg and 102 mg CP/kg of soil.

An in-parallel microcosm study was set-up using treated soil from the ex-situ demonstration.

After monitoring the biodegradation of the 14-C-pentachlorophenol, it was determined that an additional application of D6399 would increase the rate of degradation of the pentachlorophenol.

Table 1 provides a brief summary of the results. In general, the field-scale results were similar to, or exceeded, the results achieved during the previously conducted bench-scale and pilot-scale work. Treated soil concentrations ranged from 5.7 to 157 mgCP/kg and polynuclear aromatic hydrocarbons concentrations ranged from 69 to 622 mg/kg

CONCLUSIONS

The results of the in-situ and ex-situ demonstrations indicate that Daramend bioremediation is an effective remediation method for soils containing chlorophenols and polynuclear aromatic hydrocarbons. The chlorinated phenol and PAH concentrations can be reduced to below CCME criteria for industrial soils (5 mg CP/kg and 10-50 mg individual PAH/kg).

Potential	*Limits*
mobile technology	cannot remediate metals
low set-up cost	long treatment time (months)
cost-effective	require bench-scale optimization
no additional waste generated	
non-intrusive	

STATUS

A final report on the demonstration portion of the project is available. Work will continue at the full-scale level in 1995.

Project Summary prepared by Grace Dearborn Inc. for:
Technology Development Directorate,
In cooperation with:
Ontario Ministry of Environment and Energy

For Further Information Contact:
Lisa Keller, Environment Canada (819) 953-0962
D.Vallery, MOEE (416) 323-4476
Alan Seech, Grace Dearborn (905) 279-2222

Table 1: Summary of Results from in-situ and ex-situ full-scale demonstration of Daramend™ bioremediation

Parameter (mg/kg)	0 Days	118 Days	305 Days	Parameter (mg/kg)	0 Days	282 Days
In-situ	# of Areas out of 49 above CCME			Treatment Cell 1		
CP	17	2	0	CP	156.8	13.6
PAH	10	5	3	PAH	439	144.2
In-situ	Range of Concentrations in areas above CCME			Treatment Cell 2	0 Days	175 Days
CP	5.7-27.8	5.5-6.9	all<CCME	CP	102.1	1.63
PAH	69-622	102-176	113-139	PAH	619	79.1

Disclaimer/Review Notice: This document has been reviewed by the Technology Development Directorate of Environment Canada. The contents do not necessarily reflect the views and policies of agencies represented by DESRT. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

These results have led NER to conclude that its mobile ex-situ bioremediation technology:

- can remediate soils contaminated with a range of hydrocarbon compounds to MOEE parkland/residential standards
- can successfully treat soils with hydraulic conductivities as low as 2.0×10^{-6} cm/sec, and clay contents as high as 24% clay
- can provide a cost-effective option for the on-site treatment of contaminated soil

STATUS

Site operations have temporarily shut down for the winter. NER anticipates starting site operations in April, 1995 and completing the project by September 1995.

Table 1 - Treatment Results Using Spray/Percolation System

		Batch 1		Batch 2		Batch 3	
	MOEE	Non-Porous		Porous		Mixed	
	Guidelines	Initial	14 Days	Initial	14 Days	Initial	30 Days
Compound	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
TPH	100	2245	n/r	4590	<40	682	72
BTEX"s							
Benzene	0.05	<0.02	n/r	<0.02	<0.02	<0.02	<0.02
Toluene	1	<0.02	n/r	<0.02	<0.02	0.39	0.03
Ethylbenzene	0.5	8.70	n/r	5.17	0.08	0.32	0.02
Xylenes	1	56.69	n/r	8.54	0.43	1.42	0.37

Notes: n/r = no reduction
Only initial PAH's for Batch 2 were in excess of MOEE guidelines. These were treated to within MOEE guidelines in the 14 day period.
Guidelines are for Residential/Parkland use where groundwater is non-potable.

Table 2 - Treatment Results Using Probe Injection System

		Avg. of 3 analyses	Batch 1	Batch 2	Batch 3
	MOEE	of stockpile -	After	After	After
	Guidelines	(24% clay)	4 Days	7 Days	10 Days
Compound	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
TPH	100	506	55	93	90
BTEX"s					
Benzene	0.05	<0.02	<0.02	<0.02	<0.02
Toluene	1	<0.02	<0.02	<0.02	<0.02
Ethylbenzene	0.5	2.14	0.14	0.16	0.05
Xylenes	1	0.95	0.55	0.73	0.22

Notes: PAH's were not detectable in any of these samples.
Guidelines are for Residential/Parkland use where groundwater is non-potable.

This Technical Summary Sheet was prepared by NER and is based on a report entitled *Using Process Engineering to Increase the Effectiveness of the Natural Environment Recovery Mobile Ex Situ Biox Reactor Technology*. The report is in its final stages of revision and will be submitted to the MOEE and Environment Canada in March 1995.

FOR MORE INFORMATION, PLEASE CONTACT:

Lisa Keller, Technology Development Directorate, Environment Canada, (819) 953-0962

Doug Vallery, Ontario Ministry of Environment and Energy, (416) 323-4476

Figure 1 - Biox Reactor

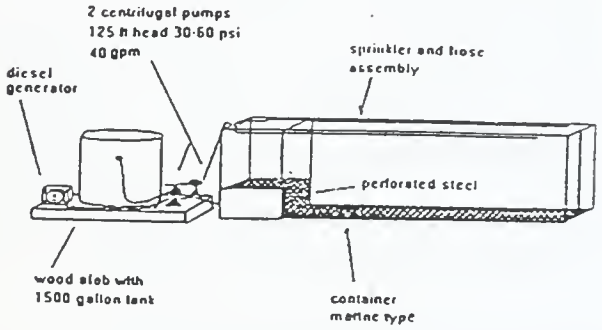
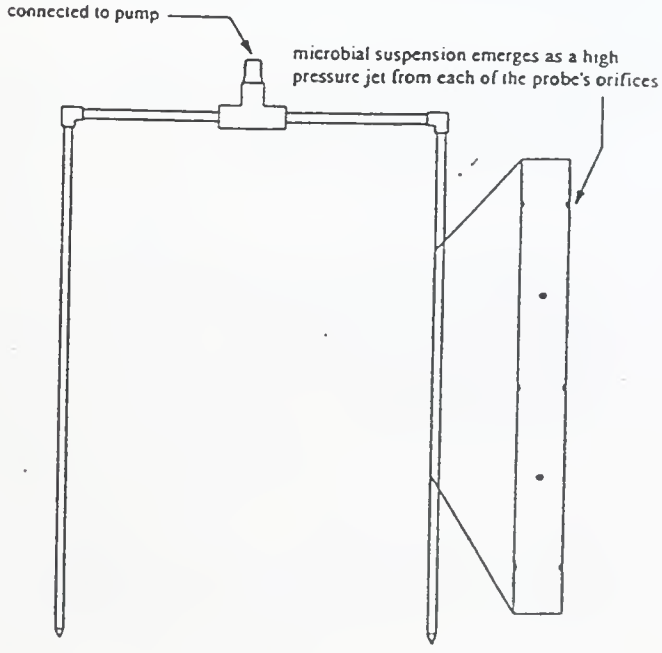


Figure 2 - Injection Probe



DISCLAIMER/REVIEW NOTICE

This document has been reviewed by the Technology Development Directorate of Environment Canada. The contents do not necessarily reflect the views and policies of agencies represented by DESRT. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

The National Contaminated Sites Remediation Program

DESRT Development and Demonstration of Site Remediation Technology

GRACE DEARBORN AND ASL ENHANCED BIOREMEDIATION AND NEAR REAL TIME MONITORING OF CONTAMINATED SOILS

Grace Dearborn Inc., Mississauga, Ontario

-Project Summary-

July 1995

INTRODUCTION

In 1989, the Canadian Council of Ministers of the Environment (CCME) established the National Contaminated Sites Remediation Program (NCSRP), which is supported and administered through federal-provincial-territorial bilateral agreements.

The DESRT (Development and Demonstration of Site Remediation Technology) program was established to address the NCSRP objective of working with Industry to stimulate the development and demonstration of new and innovative technologies having the potential to resolve problems which are critical to the environmental remediation of contaminated sites.

DESRT SUPPORTED TECHNOLOGY

This study examined the feasibility of using the Daramend™ Bioremediation Technology , developed by Grace Dearborn, for treating contaminated soil from the Pacific Place site in Vancouver, B.C. (former site of EXPO '86). The novel sequential anaerobic/aerobic treatment was used to treat soil contaminated with coal tar which contained dense non-aqeous phase liquids (DNAPL), polycyclic aromatic hydrocarbons (PAHs) and other petroleum hydrocarbons (TPHs). Also, soil samples generated from the site were analyzed by ASL Ltd. as part of its joint work on the evaluation and demonstration of six (6) near-real-time-monitoring (NRTM) techniques. Details on the ASL Ltd. NRTM work can be found in a separate DESRT Technical Summary Sheet (dated May 1995).

This demonstration was supported by the Environment Canada and the British Columbia Ministry of the Environment under the DESRT program. The total DESRT contribution was $765,000.

TECHNOLOGY DEMONSTRATION SUMMARY

Approximately 100 m^3 of excavated soil, contaminated with PAHs and petroleum hydrocarbons from a manufactured gas plant (MGP), was placed in an engineered treatment cell. Field work was conducted from November 1993 to July 1994 and involved a pilot-scale demonstration as well as a bench-scale in-parallel microcosm study, to verify field results.

The 5.5 m x 35 m cell was designed with a low permeability base and berms to fully contain the treatment area should any leachate be generated during treatment. A compacted clay treatment pad was constructed on top of the existing asphalt surface. A high density polyethylene (HDPE) liner was placed inside the clay berm providing a second level of containment for the contaminated soil. A sequence of geotextile layers and sand were placed on top of the liner to act as a buffer to protect the HDPE liner from mechanical damage which might occur during tillage activities. The contaminated soil was then placed on top of the geotextile to a depth of 0.6m.

To ensure that the initial concentration of total PAHs in the test soil were within the targeted concentration range, a preliminary field screening was conducted by ASL using an immunoassay field test kit.

An aluminum framed, polyethylene-covered greenhouse was constructed over the treatment cell to permit treatment over the winter months. The greenhouse provided a means to control soil moisture content, moderate temperature effects, reduce potential odour and dust emissions and provide a secure, limited access area for the demonstration.

A Daramend organic soil amendment of specific particle size, nutrient profile and nutrient status, was applied to the soils at a rate determined by the pre-treatment target compound concentrations and by a process optimization bench-scale microcosm study. The required mass of product was placed on the soil surface and incorporated to a depth of 0.6 m with a specialized tractor-mounted rotary tiller.

Soil in the ex-situ treatment cells was tilled once every two weeks to ensure continued uniformity of treatment with depth and to aerate the soil matrix. Irrigation was performed, with detailed monitoring to ensure an acceptable soil moisture content was maintained.

Two bench scale in-parallel treatability studies were setup using field treated soil. The first study involved spiking the soil with ^{14}C-benzo(a)pyrene and incubating it at 28°C. Benzo(a)pyrene was selected as representative of the more recalcitrant, higher molecular mass PAHs found in the Pacific Place soil. Soil for the

second treatability study was spiked with ^{14}C-phenanthrene, representing the lower molecular mass PAHs. As well as verifying field results, the treatability studies were used to examine the effects of adding additional Daramend product (combined with inorganic nutrients) to the contaminated soil versus the addition of a different Daramend product.

DEMONSTRATION RESULTS

As shown in Table1, the ex-situ demonstration area was monitored for polycyclic aromatic hydrocarbons (PAHs) and total petroleum hydrocarbons (TPHs). Initially, the average PAH concentration was 659 mg/kg. After 227 days of active Daramend treatment, a 75% reduction in PAHs was observed. It is significant to note that the total PAH concentration was reduced to below the 200 mg/kg[2] criteria, by the end of the active treatment program. The predominant species after 227 days of active Daramend treatment were some of the more recalcitrant, higher molecular mass species with 4-6 fused benzene rings. The concentrations of benzo(a)pyrene and benzo(b)fluoranthene for example were reduced from 47 to 19 mg/kg and 39 to 16 mg/kg respectively during the 227 days of active treatment. The Level C cleanup criteria for each of these compounds is 10 mg/kg.[1]

The treatment plot was decommissioned on July 3, 1994 to accommodate other previously scheduled site activities. As a result it was necessary to stockpile the amended soil at another location and to end the active maintenance program. The stockpile was sampled in September 1994 to determine the residual concentration of PAHs after 68 days of "passive" treatment. At that time the concentration of total PAHs was 106 mg/kg. The data also indicate that even the more recalcitrant PAHs continued to be degraded after completion of the demonstration program.

The initial average total TPH concentration was 4416 mg/kg. After 295 days of treatment, an 89% reduction was observed. In the bench-scale Treatability 1 study , the field treated soil showed a mineralization of 11% of the added ^{14}C-benzo(a)pyrene and a volatilization of only 0.6%. There was no added benefit to either higher rates of amendment application or to supplementing the levels of soil macronutrients. Again in Treatability 2, the field soil showed the highest mineralization of ^{14}C-phenanthrene.

CONCLUSIONS

The results of the ex-situ demonstration indicated that Daramend bioremediation is an effective method of treating MGP soils contaminated with PAHs and petroleum hydrocarbons. Concentrations of contaminants were reduced significantly, including the more recalcitrant, high-molecular weight PAHs. It should be noted that the selection and application of Daramend products are dependent upon the nature and concentration of target compounds in soil as well as other soil physical and chemical properties.

STATUS

A final sampling of the stockpiled soil will be performed to confirm that all compounds have been reduced to below the Level C cleanup criteria set for managing contaminated sites in British Columbia.

A final report was submitted in May of 1995 and is currently under review.

This Project Summary was prepared by Grace Dearborn for:
Technology Development Directorate, Environment Canada
In cooperation with:
British Columbia Ministry of Environment, Lands and Parks

For Further Information Contact:
Lisa Keller, Environment Canada (819) 953-0962
John Ward, B.C. Ministry of Environment, Lands and Parks
(604) 387-9951
Suzanne Burwell, Grace Dearborn (905) 279-2222

Table 1. Influence of Daramend Bioremediation on Concentration of PAH over Time

Parameter (mg/kg)	Number of Days of Treatment									Criteria (mg/kg)
	0	19	70	139	187	197	218	227	295	
Benzo(a)pyrene	47	34.8	39.2	29.3	26	24	21	19	12	10[1]
Benzo(b)fluoranthene	39	26.5	31.5	23.6	24	21	16.2	15.7	10	10[1]
Total PAH	659	395	366	268	230	210	173	167	106	200[2]
TPH	4416								478	2000[3]

(1) Level C Criteria B.C.(Industrial Land Use) - (2) Criteria for Managing Contaminated Sites in B.C. (B.C. MOE, 1989)
(3) Memorandum entitled Measuring Petroleum Hydrocarbons Contained in Soil and Water (B.C. MOE, 1991)

Disclaimer/Review Notice: This document has been reviewed by the Technology Development Directorate of Environment Canada. The contents do not necessarily reflect the views and policies of agencies represented by DESRT. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

The National Contaminated Sites Remediation Program

DESRT Development and Demonstration of Site Remediation Technology

APPLICATION OF A MOBILE EX-SITU BIOREACTOR TECHNOLOGY TO THE REMEDIATION OF HYDROCARBON CONTAMINATED SOIL DON RIVER VALLEY, BOROUGH OF EAST YORK, TORONTO, ONTARIO

NATURAL ENVIRONMENT RECOVERY INC., RICHMOND HILL, ONTARIO

-PROJECT SUMMARY-

March 1995

INTRODUCTION

In 1989, the Canadian Council of Ministers of the Environment (CCME) established the National Contaminated Sites Remediation Program (NCSRP), which is supported and administered through federal-provincial-territorial bilateral agreements.

The DESRT (Development and Demonstration of Site Remediation Technology) program was established to address the NCSRP objective of working with Industry to stimulate the development and demonstration of new and innovative technologies having the potential to resolve problems which are critical to the environmental remediation of contaminated sites.

An innovative technology selected for participation in the program was an ex-situ bioremediation process developed by Natural Environment Recovery (NER) Inc.

DESRT SUPPORTED TECHNOLOGY

Partial funding for this project was provided by Environment Canada and the Ontario Ministry of the Environment and Energy (MOEE) under the joint federal and provincial DESRT program. DESRT contributed $460,000 of the total $1,340,000 estimated cost for this project.

TECHNOLOGY APPLICATION

Bioremediation involves the use of micro-organisms and their metabolic processes to transform contaminants into less harmful substances such as carbon dioxide and water. With the support of the DESRT program, NER developed a mobile ex-situ bioremediation technology. The developed technology incorporates NER's proprietary aerobic bioremediation methods into transportable "Biox" reactors. These reactors contain excavated soil during treatment and are equipped with distribution systems that transport nutrients, aerobic microbes and Fiton™, NER's proprietary biostimulant. Biox reactors are also designed to recover and recycle these bioremediation process ingredients.

As part of the DESRT program, NER applied its ex-situ bioremediation technology to the remediation of some 7000 m^3 of contaminated soil. NER's mandate was to employ its Biox reactors to remediate the soil and to upgrade the soil characteristics to MOEE parkland/residential standards.

SITE HISTORY

The site chosen for this demonstration is located in the Don River Valley, and is part of the Borough of East York, Toronto. It comprises roughly 12 hectares and is near a major expressway, a bicycle path and a residential area.

Polyresins and Domtar, the former occupants, once operated their respective paint processing and paper manufacturing facilities at the site. Characterization studies were carried out between 1989 and 1991 by three independent consulting firms. They reported that the soil was contaminated with volatile organic compounds (VOC's) including ethylbenzene, xylene and styrene, and polynuclear aromatic hydrocarbon (PAH) compounds including naphthalenes and methylnaphthalenes. NER also sent out samples of excavated soil to an independent laboratory for analysis. The results showed total petroleum hydrocarbon (TPH), ethylbenzene and xylene levels to be greater than the limits set by the MOEE parkland/ residential usage. NER also found excessive PAH levels, but only in discrete areas.

PROJECT DEMONSTRATION SUMMARY

For this project NER employed eight (8) Biox reactors. Each Biox reactor was run as an independent unit with a capacity to treat 60 m^3 of soil. Operating at full capacity, the eight reactors can treat 480 m^3 of soil per batch.

Figure 1 illustrates the general design of the Biox reactor which includes a spray/percolation system. In order to deliver the microbial suspension to the soil, each reactor can use either the spray/percolation system shown or a probe injection system, both tested by NER.

Spray/Percolation System: NER designed the spray/percolation system to treat coarse-grained soils. The system consists of overhead spray nozzles mounted along the sides and front of the reactor which distribute the suspension of microbes, nutrients and Fiton™ to the top surface of the soil. Under gravity, the suspension percolates through the soil depth and drains into a sump. A pump transfers the liquids from the sump to a holding tank, thereby recycling it into the process stream. As it percolates through the soil, the microbial suspension contacts the contaminants and the breakdown of these compounds begins.

NER excavated soils from three different locations at the site and began the project by testing the spray distribution system. Using this system, NER treated three separate batches (24 reactor loads. One batch (360 m^3) failed to meet MOEE guidelines and treatment times for several of the batches also did not consistently meet NER's goal of achieving a seven-day remediation time.

NER suspected that the low hydraulic conductivities of the soils found at the site was the primary reason for the inconsistent treatment results. NER conducted soil studies and found that the site contained mostly fine-grained clay and silty soils with hydraulic conductivities between 2.0×10^{-6} cm/sec and 1.5×10^{-7} cm/sec. Under gravity alone, the flow of the microbial suspension was slow. This in tum prevented the bioremediation process from being effective. NER then proceeded to treat soils using the probe injection system.

Probe Injection System: NER designed the probe injection system for fine-grained soils that have low hydraulic conductivities. The system employs eight (8) pairs of probes per reactor (16 probes per reactor). Figure 2 illustrates the design of these probes. Each pair is inserted through the top surface of the soil, at equally spaced locations in the reactor. A pump forces the microbial suspension through the probe orifices and into various levels beneath the soil surface. The resulting kinetic energy of the fluid breaks up the clumps of packed soil and enables the microbial suspension to contact the contaminants. In addition, the simultaneous mixing of microbes, Fiton™, nutrients and contaminated soil provides an ideal environment for bioremediation.

For the initial tests of this system, NER treated soils with a clay content of 24%. These initial tests were successful, and NER treated a total of 585 m^3 of soil with this system.

NER sent all soil samples to a certified third party laboratory who analyzed samples for TPH, BTEX and PAH compounds. NER technicians prepared these samples by using a soil probe to take samples from eight random locations in the reactor. These were combined and mixed to form a composite sample for each reactor. For large batches, NER combined and mixed the composite reactor samples from up to four (4) reactors to create a composite batch sample.

TECHNOLOGY DEMONSTRATION RESULTS

Table 1 shows the results for the two batches treated to parkland/residential standards using the spray/percolation system. This system proved to be effective on porous soils. In the batch (#1) containing fine grained soils, the microbial suspension did not reach the contamination and remediation was limited to the surface layer of soil.

Table 2 shows the results for three batches treated using the probe injection system. This system is clearly more suitable for the clay/silt soil found at the site. By using this system, NER aims to consistently treat soils at a rate of one (1) batch per seven days.

NER also conducted tests of ambient air quality during excavation and treatment operations. The total volatile emissions were below Point of Impingement Standards set forth by Regulation 308 under the Environmental Protection Act. Three separate tests using Dragger Tubes to evaluate air quality within the reactors, registered no BTEX compounds above the Method Detection Limit of 10 ppm. NER limits vapour emissions by covering all stockpiled excavated soil with tarpaulins.

Treatment costs using NER's ex-situ bioremediation technology are between $50 and $60 per tonne. The total cost depends on the volume of material to be treated, the concentration and type of organic contaminants present and the clean-up levels to be achieved. This cost excludes the cost of excavation, transportation of equipment, and lab analyses.

The National Contaminated Sites Remediation Program

DESRT Development and Demonstration of Site Remediation Technology

REDUCTIVE DECHLORINATION AND ENHANCED BIOREMEDIATION OF HERBICIDE/PESTICIDE CONTAMINATED SOILS AND SEDIMENTS

Grace Dearborn Inc., Mississauga, Ontario

-Project Summary-

October 1995

INTRODUCTION

In 1989, the Canadian Council of Ministers of the Environment (CCME) established the National Contaminated Sites Remediation Program (NCSRP), which is supported and administered through federal-provincial-territorial bilateral agreements.

The DESRT (Development and Demonstration of Site Remediation Technology) program was established to address the NCSRP objective of working with Industry to stimulate the development and demonstration of new and innovative technologies having the potential to resolve problems which are critical to the environmental remediation of contaminated sites.

An innovative technology selected for participation in the DESRT program was a biologically mediated process, developed by Grace Dearborn, Inc. (Dearborn), for the treatment of herbicide and pesticide contaminated soil and sediment.

SITE HISTORY

Several sites within North America were selected to provide soil for use in the technology development. Specifically, laboratory work utilized soil from sites located in South Carolina, Oregon, Alberta and Ontario (2 sites). These sites provided a representative spectrum of chlorinated herbicides and pesticides including DDT, Toxaphene, Metolachlor, 2,4-D and 2,4,5-T. In addition, soils from other sites were used for some technology screening work.

The Uniroyal Chemical Inc. (Uniroyal) site, located in Elmira, Ontario, has been selected for the large scale technology demonstration. In December, 1993, Uniroyal excavated approximately 25,500 cubic metres of waste from two buried waste pits and placed it within a temporary storage facility. The facility includes a leachate collection and treatment system and an air ventilation and treatment system. These systems are supplemented with an ongoing monitoring program. The waste is comprised of sludges along with other waste including drums and contaminated soil from other disposal areas on the property. The waste contains chlorinated and non-chlorinated chemicals including 2,4-D; 2,4,5-T; penta and lesser chlorinated phenols; the DDT family and dioxins/furans. Uniroyal is evaluating alternatives for the permanent disposition of the waste. The evaluation process includes paper reviews and technology demonstrations such as that being conducted under this program.

DESRT SUPPORTED WORK

The DESRT program is supporting a two phase development and demonstration program of an enhanced bioremediation technology to reduce the concentrations of recalcitrant chlorinated organic compounds in solid matrices. The program involves a literature review and detailed laboratory process development followed by confirmation of process efficacy at large scale with a complex waste. The DESRT program (federal and provincial) has contributed $663,000 to the $995,000 project.

TECHNOLOGY DESCRIPTION

The reductive dechlorination technology represents a modification of the DARAMEND™ soil bioremediation technology, for which Dearborn is the worldwide licensee. The aerobic bioremediation technology utilizes organic (DARAMEND™ products) and inorganic (i.e. nutrients, pH modifiers) amendments to optimize the activity of microorganisms indigenous to a soil or waste resulting in natural destruction of organic contaminants. No microbial inoculation is required. A wide range of wastes and contaminants have been demonstrated to be amenable to remediation using DARAMEND™. Up to 3,500 tonnes (3,900 tons) of waste have been treated in a given batch. As well as reducing chemical concentrations, DARAMEND™ significantly reduces waste toxicity (i.e. to plants and earthworms).

The technology modification targets organic contaminants such as organochlorine pesticides that often degrade slowly under aerobic conditions. The modified technology involves the imposition of anoxic and oxic conditions to sequentially reductively dechlorinate complex chlorinated organics and aerobically degrade the (partially) dechlorinated breakdown products including volatile fatty acids.

Anoxic conditions are created through addition of DARAMEND™ amendments, other organic amendments and inorganic amendments (multivalent metals) and water. The DARAMEND™ amendments stimulate the biological depletion of oxygen within the

soil matrix by the aerobic and facultative microbial populations. Oxygen renewal is limited to diffusion as a result of the soil pores being nearly full of water. The multivalent metal allows a specific redox level (i.e. -400 mV) to be achieved. All the amendments are naturally occurring, non-hazardous materials.

The oxic conditions are created by reducing the saturation of the soil. This may be accomplished through natural evaporation, enhanced by tilling, as well as by increasing the soil water holding capacity through addition of DARAMEND™ amendments.

At large-scale the Dearborn approach to bioremediation is generally applied as a land farming process. Contaminated soil and amendments are blended using a rotary tiller with an effective penetration of 0.6 m. The rotary tiller is driven by an agricultural tractor. The tilling serves to homogenize the amended soil and also to aerate the soil when aerobic conditions are targeted. Water content is one critical process parameter and is adjusted using agricultural irrigation equipment. A cover (i.e. tarpaulin and/or a greenhouse) may be used to prevent the addition of water from precipitation events and to minimize evaporation at other times. The cover negates the requirement for a leachate collection system as the soil or waste being treated is maintained below saturation. The technology has been applied to excavated waste on-site and also to surficial soil (upper 0.6 m) in-situ.

TECHNOLOGY DEMONSTRATION SUMMARY

Laboratory studies were conducted using soil from eight locations across North America. The soils represented a wide range of physical and chemical properties. Namely, sand and total organic carbon content ranged from 3.6 to 98% and 0.3 to 5.6% respectively. The studies were to optimize the two distinct phases of the treatment process i.e. the anoxic and oxic phases and evaluate the fate of the contaminant being studied. Studies were carried out as soil microcosms using 100 to 250 g of soil. Depending on the experimental objective the microcosms were contained in 250 mL to 1,000 mL glass jars.

The objective of the anoxic studies was to determine the most effective treatment to achieve and maintain a low redox state in the soil. The key response variables monitored were soil redox potential measured by redox probe and, for soils containing chlorinated organics, chloride concentration (one endpoint of reductive dechlorination). The concentration of the chlorinated contaminant of concern was used to verify dechlorination.

The anoxic optimization studies were structured to include a screening and validation phase. The former involved the testing of a wide number of soil amendments (DARAMEND™, multivalent metals and others) on a single soil to determine the amendment(s) with the most effect on the soil redox. Based on this screening effort, the second phase involved a broader range of soils and a selected number of amendments.

The oxic optimization studies involved an evaluation of the efficacy of amendments in removing volatile fatty acids. The key response variables monitored were soil redox, pH and volatile fatty acids. The previously demonstrated DARAMEND™ technology was the focus of much of the efforts however other amendments such as solid phase oxygen sources were also evaluated.

Repeated cycles of the anoxic and oxic treatment phases were applied to validate that the combined treatment was effective in reducing the measurable concentration of contaminant in the soil phase. The key response variable monitored was the chlorinated organic compound concentration.

The fate studies involved radioisotope techniques using ^{14}C isomers of target compounds including DDT and 2,4,5-T to assess the key fates of selected compounds. Methane, carbon dioxide, uptake in biomass, partial breakdown to extractable organics and volatile organics were endpoints investigated. The study required use of multiple trapping techniques (i.e. NaOH trap for carbon dioxide) and extraction techniques.

The final component of the study will be a full-scale demonstration. The demonstration will involve treatment of several hundred tonnes of waste in a lined and covered treatment cell. The objective will be to verify that the results observed in the laboratory can be translated to the field using full-scale equipment. Specifically, the cell will be constructed of clay berms lined by high density polyethylene and covered by a Gothic style greenhouse. To ensure no volatiles are released to the environment during treatment, the headspace of the greenhouse will be maintained under negative pressure and the captured headspace air will be treated using an activated carbon unit. Waste treatment will be implemented using a deep rotary tiller powered by a farm tractor. Irrigation will be through a market garden irrigation system fed by creek water.

DEMONSTRATION RESULTS

The key results for each phase of the project completed to date are summarized in the bullets listed below. In addition, Table 1 summarizes the results of selected cycled treatments, validating treatment efficacy.

- the most effective treatment resulted in soil redox states as low as -550 mV. The low redox could be maintained for periods of approximately 3 weeks. Other treatments resulted in significantly higher redoxes. While the control redox (oxic) was approximately 250 mV;

- a strong negative redox resulted in an increasing chloride concentration, increasing volatile fatty acid concentration and decreasing pH with time. The chloride concentration increased rapidly then decreased with time. The most significant change in soil chloride concentration was generally observed in less than 7 days of strong negative redox conditions;

- the lower the redox state attained, the greater the dechlorination observed as measured by an increasing chloride concentration;

- oxic conditions resulted in a return of pH to the pre-anoxic pH, decreasing volatile fatty acid concentration and increased redox. Significant changes were generally observed in several days;

- optimal oxic treatment involved frequent tillage, potentially coupled with application of DARAMEND™ amendments, depending on the soil treated. No beneficial effect was observed when solid phase oxygen sources were used;

- preliminary results from the fate studies show that the recovery of chlorinated compounds as methane and volatile compounds is negligible. Generally speaking, carbon dioxide evolution was limited however, for 2,4-D significant carbon dioxide evolved (i.e. 20% of the spiked mass was recovered in the NaOH trap); and

- coupled treatment resulted in excellent decreases in contaminant concentration as shown in Table 1.

STATUS

The project is currently moving from closure of laboratory optimization and fate definition studies to initiation of field projects. The optimization work has shown rapid and consistent decreases in the concentration of chlorinated organics including DDT; Metolachlor; 2,4-D; and 2,4,5-T.

The field component of the project will take place at the Uniroyal Chemical facility located in Elmira, Ontario. The material to be treated consists of approximately 300 tonnes of waste containing a number of materials including soil, sludge and tank bottoms. The principal contaminants to be targeted in the waste are 2,4-D and 2,4,5-T although the effect of treatment on many other chlorinated and non-chlorinated organics will be evaluated. Mobilization is likely for October/November of 1995.

Another field project (not receiving funding under the DESRT program) is scheduled to commence in South Carolina this year. The project will target DDT and many other chlorinated pesticides. Treatment will be conducted on the surficial 2 feet of soil, in-place, and covered by a greenhouse.

Project Summary prepared by Grace Dearborn Inc. for:
Environmental Technologies Advancement Directorate
and the
Ontario Ministry of Environment and Energy

For Further Information Contact:
Lisa Keller, Environment Canada (819) 953-0962
Gilles Castonguay, Ontario MOEE (416) 323-5214
Alan Seech, Grace Dearborn (905) 279-2222

Table 1: Concentrations of selected chlorinated organics initially and following a specified length of treatment

Contaminant	Initial (mg/kg)	Final (mg/kg)	Treatment Time (days)	Treatment Cycles	DRE (%)*
Soil 1 - DDT	225	113	47	2	50
Soil 1 - Toxaphene	577	320	47	2	45
Soil 2- 2,4,5-T	650	370	131	2	43
Soil 2- 2,4-D	4,950	2,000	131	2	60
Soil 3- Metolachlor	139	5.2	186	4	96
Soil 4- 2,4,5-T	566	344	47	2	39

Note that the final concentrations represent concentrations following the stated treatment time. Additional treatment will result in further contaminant reductions.

* Destruction and removal efficiency.

Disclaimer/Review Notice: This document has been reviewed by the Environmental Technologies Advancement Directorate of Environment Canada. The contents do not necessarily reflect the views and policies of agencies represented by DESRT. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

The National Contaminated Sites Remediation Program

DESRT Development and Demonstration of Site Remediation Technology

IN-SITU, ON-SITE BIOREMEDIATION OF WOOD TREATMENT SOILS CONTAINING CHLORINATED PHENOLS AND PAH'S - GRACE DEARBORN INC.
Mississauga, Ontario

- PROJECT SUMMARY -

June 1994 (UPDATE)

INTRODUCTION

In 1989, the Canadian Council of Ministers of the Environment (CCME) acknowledged the need for a consistent national approach for the prioritization and remediation of high risk contaminated sites in Canada. In response to this need, CCME established the National Contaminated Sites Remediation Program (NCSRP), which is supported and administered through federal-provincial-territorial bilateral agreements.

The DESRT (Development and Demonstration of Site Remediation Technology) program is a component of the NCSRP, and was established to address the NCSRP objective to work with industry to stimulate the development and demonstration of new and innovative technologies having the potential to resolve problems which are critical to the environmental remediation of contaminated sites.

An innovative technology selected for participation in the DESRT Program was the use of a solid-phase organic soil amendment technology developed by Grace Dearborn Inc. The study was performed by the vendor and was jointly funded by Environment Canada and the Ontario Ministry of Environment & Energy (under the DESRT program), and Grace Dearborn Inc.

DESRT SUPPORTED WORK

The DESRT program supported a pilot-scale field demonstration, consisting of both in situ and ex situ / on-site experimental plots. Total DESRT support was $370,500. The main objectives of the research project are outlined in the December 1993 Technical Summary Sheet issue.

TECHNOLOGY DESCRIPTION

The Daramend™ Bioremediation Technology was developed by Grace Dearborn Inc. in coordination with Environment Canada. The technology involves the use of solid phase organic amendments of specific particle size, nutrient profile, and nutrient release kinetics.

TECHNOLOGY DEMONSTRATION SUMMARY

This study was conducted over the course of two years (1991-1992). Field work involved two in-situ demonstrations of the technology, the first in 1991, and the second in 1992. Two ex-situ (on-site) demonstrations (the first in 1991, and the second in 1992) were also conducted. Microcosms were set up in the laboratory to verify the results of the field work.

In the 1991 in-situ demonstration, twenty-one plots were set up to test six treatments and one control in triplicate. Each plot, delineated with galvanized-steel surface and sub-surface barrier walls, covered an area of 10 m^2 and served to treat approximately 8.4 tonnes of soil. An undisturbed 2 m buffer zone surrounded each plot.

The treatments tested were:

i) Tillage + Irrigation (Plots 2A-2C)
ii) Tillage + Irrigation D6380 (Plots 3A-3C)
iii) Tillage + Irrigation + Inoculation (Plots 4A-4C)
iv) Tillage + Irrigation + D6380 + Inoculation(Plots 5A-5C)
v) Tillage + Irrigation + D6390 + Inoculation + (Plots 6A-6C)
vi) Tillage + Irrigation + D6380 + Inoculation + controlled -release inorganic nutrients (Plots 7A -7C)

The "static" control consisted of undisturbed site soil. D6380 and D6390 are Daramend™ product numbers and refer to low- nutrient-content organic amendment, and high-nutrient -content organic amendment respectively.

The 1992 in-situ demonstration dealt with PAH concentrations higher than those found in the 1991 in-situ demonstration. Nine plots were set up. Three treatments were performed in triplicate. The treatments tested were:

i) Tillage + Irrigation (Plots 1-3)
ii) Tillage + Irrigation + D6380 (Plots 4-6)
iii) Tillage + Irrigation + D6380 + Controlled-release inorganic nutrients (Plots 7-9)

The 1991 ex-situ (on-site) demonstration served to treat approximately 10 tonnes of soil. The treatment area measured 3 m x 4 m and was surrounded by a 1 m wide buffer (control) zone. The depth of soil was approximately 50 cm. The treatment area was entirely enclosed by a greenhouse and heating allowed for year round soil treatment.

The 1992 ex-situ (on-site) demonstration served to demonstrate the technology at a larger scale, treating approximately 100 tonnes of soil. The treatment cell measured 6 m x 37 m and was surrounded by a 1 m wide buffer (control) zone. The depth was approximately 50 cm.

The 1991 ex-situ (on-site) demonstration tested the organic amendment technology with weekly tillage and irrigation. In the 1992 ex-situ demonstration the soil was also treated with controlled-release inorganic nutrients. Controls in both demonstrations consisted of undisturbed site soil.

DEMONSTRATION RESULTS

The 1991 in-situ demonstration data indicated that initial total chlorinated phenol concentrations varied between the plots. During 112 days of treatment, chlorinated phenol concentrations were reduced to below the CCME remediation criteria for industrial and commercial soils (5 mg/kg for each listed chlorinated phenol) in soil treated with organic amendments alone or in combination with bacterial inoculation (treatments ii, iv, and v as described above). Chlorinated phenol concentrations were also reduced to below the CCME remediation criteria in soil receiving only tillage and irrigation (treatment i), however, this result can be attributed to the fact that the soils in plots 2A-2C had low initial total chlorinated phenol concentrations (mean = 6.6 mg/kg). The remediation criteria may not have been achieved had the initial contaminant concentration been

higher. Chlorinated phenol concentrations were also reduced in soil treated with bacterial inoculation alone or in combination with an organic amendment and supplemental nutrients (treatments iii, and vi), however, after 112 days of treatment, the total chlorinated phenol concentrations were 6.7 mg/kg and 6.8 mg/kg respectively, and remained above the CCME remediation criteria.

Data from the 1992 in-situ demonstration indicated that after 147 days of treatment, the total PAH concentration in the soils treated with organic amendment alone (treatment ii as described above) was reduced by 79%, from 18,496 mg/kg to 3,870 mg/kg, and by 68%, from 7,577 mg/kg to 2,409 mg/kg in soil treated with an organic amendment and supplemental nutrients (treatment iii). The total PAH concentration in the soil receiving tillage and irrigation alone (treatment i) was reduced by 48%, from 16,933 mg/kg to 8,736 mg/kg, however, concentrations of the more refractory high molecular weight PAHs with four to six fused benzene rings (e.g. fluoranthene, pyrene, and benzo(a)anthracene) were only reduced in soils subjected to treatments ii or iii.

Data from the 1991 ex-situ (on-site) demonstration, which treated 10 tonnes of soil, indicated that treatment with organic amendment alone reduced the total chlorinated phenol concentrations from an initial level of 702 mg/kg to 4 mg/kg (below the CCME remediation criteria for all listed chlorinated phenols) in 345 days. The total PAH concentration was reduced by 97%, from 1442 mg/kg to 36 mg/kg in the same time period. The concentrations of all CCME remediation criteria listed PAHs, including the most refractory high molecular weight PAHs (e.g. benzo(a)pyrene and indeno(1,2,3-c,d)pyrene), were reduced to below the CCME remediation criteria for industrial and commercial soils (10 mg/kg). Concentrations of PAHs with two or three fused-benzene rings (e.g. fluorene and phenanthrene) were rapidly reduced to below the remediation criteria, usually within 21 days of treatment.

Standard toxicological tests, including earthworm mortality and seed germination, were performed on soil taken from the treated area and the control area after completion of the demonstration. The tests indicated that Daramend treatment had reduced or eliminated the soil's toxicity. Earthworms exposed to soil from the control area died in four days (100% mortality), while all earthworms exposed to the Daramend-bioremediated soil survived for the full 28 days of the assay (0% mortality). Similar reductions in toxicity of the treated soil were revealed by seed germination assays. For example oat seeds added to the untreated control soil failed to germinate (0% germination) while in the Daramend-bioremediated soil 93% of the seeds germinated. In an agricultural soil with no history of contamination, oats germinated at the same rate (93%) as in the bioremediated soil.

Data from the 1992 ex-situ (on-site) demonstration, which treated 100 tonnes of soil, indicated reductions in total chlorinated phenol and PAH concentrations from initial levels of 691 mg/kg and 1568 mg/kg respectively, to 8 mg/kg and 96 mg/kg respectively, in 291 days. Given the results of the 1991 ex-situ demonstration, it is reasonable to assume that CCME remediation criteria would be achieved for all compounds with additional treatment time. Table 1 summarizes the results of all four demonstrations.

CONCLUSIONS

The results of the four demonstrations indicate that Daramend-bioremediation is an effective remediation method for wood treatment soils containing chlorinated phenols and PAHs. Significantly, Daramend treatment resulted in attainment of CCME remediation criteria for industrial soils and reduced or eliminated soil toxicity as measured by standard tests. The most effective treatment applied to soils, as indicated by this demonstration involved the application of Daramend product D6380. The selection and application rates of Daramend products are dependant on the nature and concentration of target compounds in soil as well as other soil physical and chemical properties.

STATUS

Work is continuing. A full-scale demonstration of Daramend™ bioremediation technology was initiated in the summer of 1993. The full-scale in-situ demonstration was designed to treat approximately 0.5 hectares (4800 m^2) of the site. The area was divided into 49 individual zones of approximately 100 m^2 each. After 305 days of Daramend treatment the concentrations of all CCME listed chlorinated phenols were reduced to below the CCME remediation criteria for industrial and commercial soil in all zones. The concentrations of all CCME listed PAHs were reduced to below the CCME remediation criteria for industrial and commercial soil in all zones, with the exception of 3 zones which remained just above the CCME criteria for two of the most refractory high molecular weight PAHs, benzo(a)pyrene and benzo(b)fluoranthene (CCME criteria = 10 mg/kg for each). The remediation criteria for all compounds in all zones is expected to be achieved at next sampling.

Project Summary prepared by Wastewater Technology Centre and Grace Dearborn Inc. for:
DESRT Program, Technology Development Directorate
Environmental Protection Service, Environment Canada
Hull, Quebec

In cooperation with:
Ontario Ministry of Environment & Energy

For Further Information Contact:
G. Hardy, Environment Canada (819) 953-0962
D. Vallery, Ontario Ministry of Environment & Energy
(416) 323-4476

Table 1 : Summary of the Demonstration Results.

Demonstration Data : 1991 in-situ			
Treatment	Total Chlorinated Phenol Concentration (mg/kg)		Achieved CCME Criteria (Y/N)
	Initial	final (after 112 days)	
I	9.6	2.8	Y
II	26.1	3.9	Y
III	42.6	6.7	N
IV	24.5	4.2	Y
V	8.6	1.5	Y
VI	29.7	6.8	N

Demonstration Data : 1992 in-situ			
Treatment	Total PAH Concentration (mg/kg)		Reduction in PAH (%)
	Initial	final (after 147 days)	
I	16933	8736	48
II	18496	3870	79
III	7577	2409	68

Demonstration Data : 1991 ex-situ			
Treatment :	Organic amendment		
Contaminant	Concentration (mg/kg)		Achieved CCME Criteria (Y/N)
	Initial	final (after 345 days)	
Total PAH	1442	36	Y
Total Chlorinated Phenol	702	4	Y

Demonstration Data : 1992 ex-situ			
Treatment :	Organic amendment with controlled-release of inorganic nutrient		
Contaminant	Concentration (mg/kg)		Achieved CCME Criteria (Y/N)
	Initial	final (after 291 days)	
Total PAH	1568	96	N
Total Chlorinated Phenol	691	8	N

DISCLAIMER/REVIEW NOTICE
This document has been reviewed by the Technology Development Directorate of Environment Canada. The contents do not necessarily reflect the views and policies of agencies represented by DESRT. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

The National Contaminated Sites Remediation Program

DESRT Development and Demonstration of Site Remediation Technology

FIELD VALIDATION OF TEST METHODS FOR SOLIDIFIED WASTE EVALUATION
WASTEWATER TECHNOLOGY CENTRE
Burlington, Ontario

-PROJECT SUMMARY-

April 1995

INTRODUCTION

In 1989, the Canadian Council of Ministers of the Environment (CCME) acknowledged the need for a consistent national approach for the prioritization and remediation of high risk contaminated sites in Canada. In response to this need, CCME established the National Contaminated Sites Remediation Program (NCSRP), which is supported and administered through federal-provincial-territorial bilateral agreements.

The DESRT (Development and Demonstration of Site Remediation Technology) program is a component of NCSRP. It was established to address the NCSRP objective of working with industry to stimulate the development and demonstration of new and innovative technologies with the potential to resolve problems that are critical to the environmental remediation of contaminated sites.

A novel project selected for participation in the DESRT program was a field validation study of test methods for solidified waste evaluation, which was initiated in January, 1993.

DESRT SUPPORTED TECHNOLOGY

Stabilization/solidification (s/s) with cementitious binders is used to improve the physical and chemical properties of wastes prior to utilization or disposal.

Unfortunately, although a great variety of test methods have been developed all over the world, there is no standard procedure for evaluating the efficacy of a s/s process.

The Wastewater Technology Centre (WTC) has proposed a series of test methods for evaluating the intrinsic physical and chemical properties of a solidified waste (Environment Canada Report EPS 3/HA/9). The tests examine the ability of the solidified waste to retain contaminants over the long term, in a variety of utilization and disposal scenarios.

Although previous work has provided an extensive background database of state-of-the-art solidified waste properties, a relationship between properties measured in the laboratory and the behaviour of solidified waste in the field has yet to be established, and is the focus of current work at WTC.

To date, funding for this project has been supplied by the Ontario Ministry of Environment and Energy, the British Columbia Ministry of Environment, Lands and Parks, and Environment Canada under DESRT, the joint provincial /federal funding program ($540,000), as well as the United States Environmental Protection Agency ($106,000).

Expertise and in-kind contributions have been made to the project by Laidlaw Environmental Services Ltd., Shaw-Eurocan Environmental Inc., Standard Slag Cement, Lafarge Canada Inc., National Silicates Ltd., and Beachville Lime.

TECHNOLOGY APPLICATION

The proposed test methods for solidified waste evaluation will be used by waste generators, providers of s/s technology, and regulators, to investigate waste management alternatives which are both economically and environmentally acceptable.

Field validation of the test methods will facilitate confident adoption of the methods by potential users.

TECHNOLOGY DESCRIPTION

Mixing of hazardous wastes with hydraulic binders, such as portland cement or pozzolanic power plant fly ash, can immobilize contaminants in two ways: 1) by chemically binding them in an insoluble form, and 2) by physically trapping them in a rigid, impermeable and durable matrix.

The proposed solidified waste evaluation protocol examines basic characteristics of the solidified waste matrix, and chemical and physical immobilization of contaminants, to assess the environmental stability of a solidified product.

The field validation study of the protocol has been initiated with the following objectives:

1) to compare and relate the laboratory and field leaching characteristics of a solidified product, and

2) to critically examine the proposed criteria dealing with the performance of a solidified product undergoing the specified laboratory tests.

SUMMARY OF FIELD VALIDATION STUDY

The field validation study of the WTC protocol is scheduled to take place over an initial period of three years. The project may be divided into three main phases:

I. Waste selection and s/s formulation development
II. Field solidification
III. Landfill cell monitoring and evaluation of results

Field solidification was performed in October, 1993, and the first year of monitoring has now been completed.

PROJECT DEMONSTRATION SUMMARY

An electric arc furnace dust was chosen for the field work. This material is a very fine, dark reddish brown dust, containing high levels of boron, chromium, copper, lead, mercury, nickel and zinc. Development of a s/s formulation involved initial factorial design experiments with generic cementing additives to select an effective cementing system, followed by selection of admixtures, based on early strength. A binder system composed of 62.5% granulated blast furnace slag, 25% lime, 7.5% silica fume, and 5% sodium silicate, with a Na_2O to SiO_2 ratio of 1:1, was decided upon. Testing batches with different binder to waste ratios according to the WTC solidified waste evaluation protocol resulted in selection of a binder to waste ratio of 4:3 for the field work. As would be expected for most monolithic solidified wastes, the solidified product passes the solidified waste evaluation protocol by physically immobilizing contaminants.

A pilot-scale landfill was placed in the 6 m deep compacted clay cover of the hazardous waste landfill operated by Laidlaw Environmental Services near Sarnia, Ontario. The experimental cell was constructed as an inverted pyramid, with a maximum depth of 3 m at the centre of the pyramid, and an 18 m x 18 m base. The liner and leachate collection system for the cell is composed of (from the bottom up): the compacted site clay, a layer of geotextile, a layer of drainage net, a flexible membrane liner, and an additional layer of geotextile. Leachate is collected from above and below the flexible membrane. A 0.5 m layer of silty sand, with a permeability of 10^{-6} m/s, was placed to surround the solidified material.

Mixing of the solidified waste was performed using a mobile treatment system composed of a central high shear concrete mixer, surrounded by hoppers on load cells for each of the components of the mix. Four hundred and fourteen (414) 0.15 m^3 batches of solidified waste were prepared over a period of 11 days, to yield approximately 63 m^3 of solidified material in the cell. The fresh solidified waste was transported from the mixer using a piston pump, and was vibrated in place with a pencil vibrator.

Cores of the solidified waste mass were taken 56 days, 6 months and one year after solidified waste placement, and will be taken every 6 months for a further year. Core samples are tested in the laboratory according to all three levels of the WTC protocol, in parallel with solidified waste samples cured under laboratory conditions.

Leachate is being collected at approximately monthly intervals from the collection pipes and soil moisture probes in the sand surrounding the waste. The leachate is analyzed for the major contaminants, conventional parameters, i.e., pH, ORP, TSS, TDS, and other parameters of interest, such as calcium, aluminum, carbonate, and other anions.

TECHNOLOGY DEMONSTRATION RESULTS

Physical properties of the field samples were found to vary more than is typical of laboratory samples. The strength of the 56 day core sample was low, but the expected high strength was found for the 6 month core sample, showing that field curing took place more slowly. In-situ hydraulic conductivity appeared to be several orders of magnitude higher than laboratory results.

STATUS

Boreoscopy of a core hole are also planned, to investigate the continuity of the monolith in the field cell. Collection, evaluation and comparison of the laboratory and field leaching data is presently on-going. A statistical comparison will be conducted to examine any significant differences between the WTC protocol results for waste solidified in the field vs results for waste solidified in the laboratory, and to investigate changes in solidified waste properties with time.

The relationship between field properties and laboratory results will be investigated. The quality of the leachate will be examined critically, in view of the conclusions made regarding the solidified waste quality based on the results of the WTC protocol.

An Interim Report for the site and waste preparation has been submitted and is currently undergoing review by the funding partners. A final report will be prepared for March, 1996.

Project Summary prepared by Wastewater Technology Centre for:

DESRT Program, Technology Development Directorate
Environmental Protection Service, Environment Canada

In cooperation with:

Ontario Ministry of the Environment and Energy
British Columbia Ministry of the Environment, Lands and Parks
United States Environmental Protection Agency

For Further Information Contact:

L. Keller, Environment Canada (819) 953-0962
J. Stegemann, Wastewater Technology Centre (905) 336-4738
G. Castonguay, MOEE (416) 323-5214
Kul Bindra, BC Environment , Lands and Parks (604) 387-3648

DISCLAIMER/REVIEW NOTICE:

This document has been reviewed by the Technology Development Directorate of Environment Canada. The contents do no necessarily reflect the views and policies of agencies represented by DESRT. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

Environment Environnement

Ontario

The National Contaminated Sites Remediation Program

DESRT Development and Demonstration of Site Remediation Technology

August 1994

- PROJECT SUMMARY -

FIELD-BASED PILOT SCALE REMEDIATION TRIALS FOR INDUSTRIALLY-CONTAMINATED ENVIRONMENTAL HAZARDOUS SOILS

TALLON METAL TECHNOLOGIES INC. (GUELPH, ONTARIO)

INTRODUCTION

In 1989, the Canadian Council of Ministers of the Environment (CCME) acknowledged the need for a consistent national approach for the prioritization and remediation of high risk contaminated sites in Canada. In response to this need, CCME established the National Contaminated Sites Remediation Program (NCSRP), which is supported and administered through federal-provincial-territorial bilateral agreements.

The DESRT (Development and Demonstration of Site Remediation Technology) program is a component of NCSRP. It was established to address the NCSRP objective of working with industry to stimulate the development and demonstration of new and innovative technologies having the potential to resolve problems that are critical to the environmental remediation of contaminated sites.

An innovative technology selected for participation in the DESRT program was an integrated heavy metal/organic contaminant recovery technology developed by Tallon Metal Technologies of Guelph, Ontario. This project was conducted with equal funding by the Ontario Ministry of the Environment and Energy and Environment Canada under the DESRT program. Total DESRT support was $409,054

SITE HISTORY

The Ataratari site encompasses approximately 32 hectares of land near the central business core of Toronto which had been secured for residential/commercial redevelopment by the City of Toronto and the Province of Ontario. Historically, the site was the location for foundries, scrap yards, rail lands and coal yards. As a result of this past industrial activity, a substantial portion of the site had become contaminated with heavy metals, including lead (Pb), Copper (Cu), zinc (Zn) and cadmium (Cd), and organics, primarily polyaromatic hydrocarbons (PAHs). Preliminary testing of excavated soils from the site revealed that the soils exceeded the Ontario Ministry of the Environment guidelines for re-use with respect to these contaminants, and it has been estimated that a minimum of 500,000 tonnes of soil on the site does not meet the less stringent commercial/industrial usage criteria.

TECHNOLOGY DESCRIPTION

In the Tallon process (Figure 1), contaminated soil is initially pre-screened to remove large debris (eg. stone, brick, etc.). The screened soil is subsequently scrubbed in a wet scrubber, which washes and separates coarse soil components.

The soil slurry is then subjected to size, magnetic, and gravity separations to yield additional clean soil products. Recovered metal products were found to be useful feedstocks at an off-site metal recycling facility. The treated soil slurry, free of coarse metal contaminants, is subjected to chemical treatment using specialized reagents and physical organic separators to recover organic contamination product (OP-1). The organic-depleted soil slurry is treated in a hydrometallurgical circuit where fine metal contamination is selectively leached to solution and then recovered using Vitrokele™ metal selective adsorbents. The metal-depleted slurry is subsequently washed, dewatered and recombined with the other decontaminated soil products for on-site re-use, while recovered metal product (MP-5) is removed for off-site recycling.

TECHNOLOGY DEMONSTRATION SUMMARY

A pilot-scale treatment demonstration study was conducted at an off-site location using four bulk samples (35 tonnes each) of contaminated soils from the Ataratiri site in Toronto. As shown in Table 1 for two of the bulk soil samples, the levels of contamination in each of the soil types warranted a fairly broad range of remediation requirements with respect to various target heavy metals and PAH contaminants. Each soil sample, and a composite of all four samples were subjected to continuous treatment in an ex-situ treatment facility capable of throughputs ranging between 0.5 to 1.5 tonnes per hour.

DEMONSTRATION RESULTS

Selected results of the treatment of two of the soil samples (Table 1) using the Tallon process indicated the following key findings:

- Each of the soil samples were effectively treated using the fully integrated steps of coarse metal contamination recovery, organic contaminant recovery and hydrometallurgical contaminant recovery (eg. for individual PAH's, up to 95% recovery was obtained; for metals, overall recoveries ranged from 60% for Pb to 90% for Cd)

- Treatment by-products were highly enriched in recovered contaminants and suitable for off-site recycling.

- Based on the characterization and treatment of the four soil samples, of the 500,000 tonnes of Ataratiri soils, it is estimated

that 70% of the soil will require organic treatment due to one or more PAH contaminants, 100% of the soils at the site will require partial treatment for metals contamination, and 35% of the soils will require complete metal treatment.

- The vendor (Tallon) claimed that, based on the findings in the demonstration study, a cost analysis for full-scale remediation of the Ataratiri site indicated soil treatment costs of approximately $100 per tonne of contaminated soil.

STATUS

The information presented in this summary is based on the vendor's report entitled *Decontamination of Ataratiri Soils Contaminated with Heavy Metals and Organics: A Demonstration of Tallon Metal Technologies Inc.'s Soil Remediation Technology*, September 19

Project Summary prepared by the Wastewater Technology Centre for the DESRT Program,
Technology Development Directorate
Environmental Protection Service, Environment Canada
Hull, Quebec K1A 0H3

In cooperation with The Ontario Ministry of Environment and Energy (MOEE)
For further information contact:

G. Hardy, Environment Canada (819) 953-0962
D. Vallery, MOEE (416) 323-4476

Table 1. Overall Treatment Results for Ataratiri Soils AT-3 and AT-4

CONTAMINANT [a]	CONTAMINANT LEVEL (µg/g dry weight)				REMEDIATION CRITERIA COMMERCIAL/INDUSTRIAL & (RESIDENTIAL/PARKLAND)	
	SOIL AT-3		SOIL AT-4			
	Before Treatment	After Treatment	Before Treatment	After Treatment	Ontario MOEE[6]	CCME[5]
Arsenic	*32[b]*	< 25	*32*	20	50 (25)	50 (30)
Cadmium	**9.25**	2	*7.5*	< 1.7	8 (4)	20 (5)
Copper	175	120	**2400**	*297*	300 (200)	500 (100)
Lead	**1025**	480	**3300**	*681*	1000 (500)	1000 (500)
Mercury	*1.4*	0.6	0.6	0.3	2 (1)	10 (2)
Nickel	70	50	**400**	60	200 (200)	500 (100)
Zinc	**1300**	481	**2300**	768	800 (800)	1500 (500)
Oil/Grease	8792	2559	3261	966	1% (1%[7])	5000 (1000)
Benzo(a)anthracene	*4.4*	< 1.0	*2.0*	< 1.0	-	10 (1)
Benzo(a)pyrene	*4.8*	< 1.0	*1.6*	< 1.0	-	10 (1)
Benzo(b)fluoranthene	**12.4**	*3.0*	*1.3*	< 1.0	-	10 (1)
Indeno(1,2,3-cd)pyrene	*1.5*	< 1.0	< 1.0	< 1.0	-	10 (1)
Pyrene	*12.15*	1.0	5.0	< 1.0	-	100 (1)
Percentage of soil recovered for re-use on-site	0[1] > industrial	86[2] residential	0[3] Reg.347 registerable waste	84[4] industrial		

[a] Only target values of significance shown.
[b] Soils were analyzed for 24 metals and 16 PAH's.
** ** value exceeds residential guideline.
value exceeds industrial guideline.
1 Exceeds commercial/industrial guideline.
2 Meeting commercial/industrial ≈ meeting residential guidelines[c].
[c] 3 Expected with simple detergent wash of coarse products during treatment.
Exceeds industrial guidelines, fails Reg. 347
4 leachate for Pb.
5 Meeting industrial guidelines.
6 Values from interim report (CCME, 1991); all values µg/g dry weight unless otherwise noted.
7 MOEE; all values µg/g dry weight unless otherwise noted.
Guideline is for fresh oil; for weathered oil (minimum of 2 years exposed on site), the guideline is 2%.

DISCLAIMER/REVIEW NOTICE

This document has been reviewed by the Technology Development Directorate of Environment Canada. The contents do not necessarily reflect the views and policies of agencies represented by DESRT. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

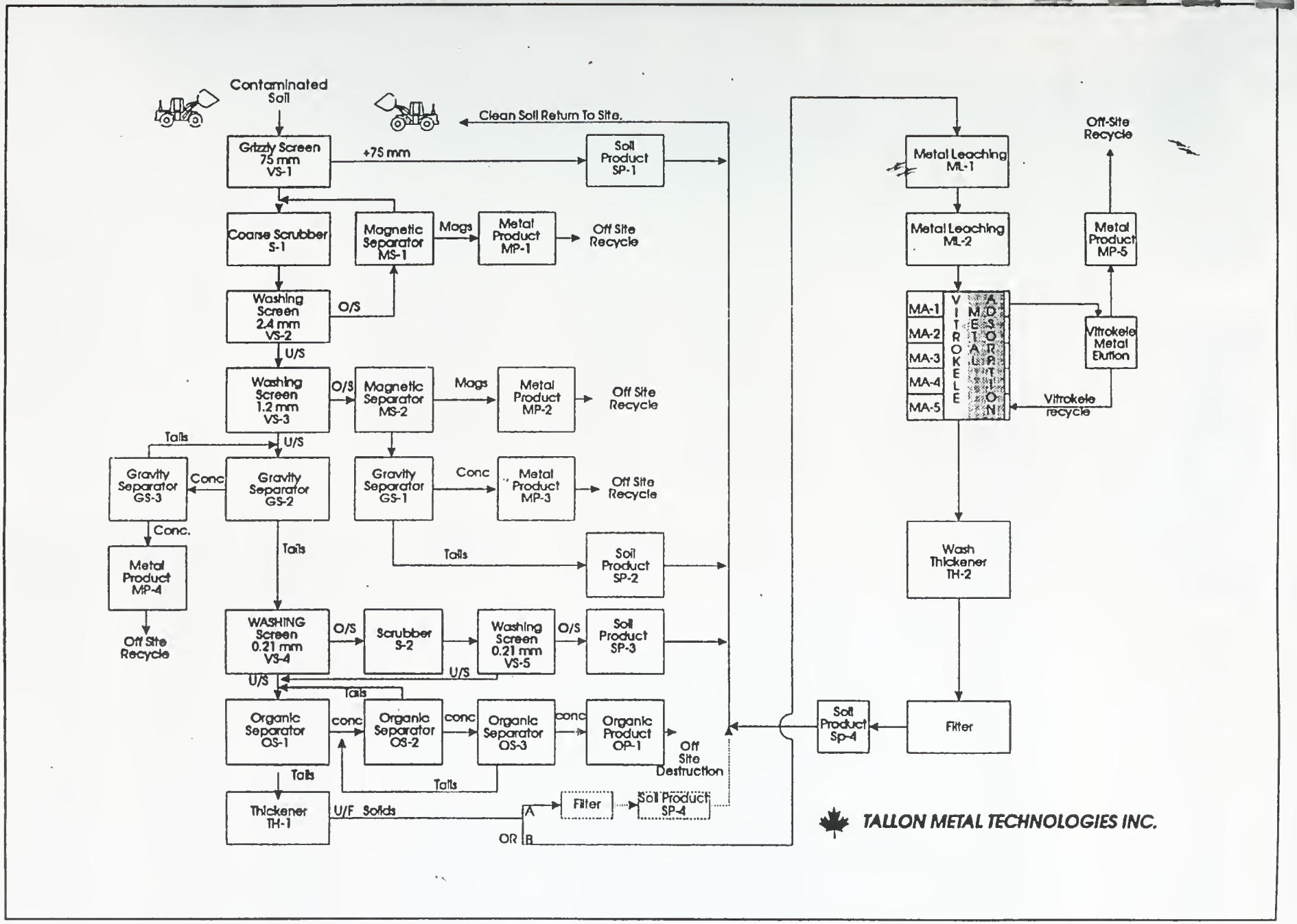


Figure 1. Schematic Flowsheet of Tallon Remediation Process

The National Contaminated Sites Remediation Program

DESRT Development and Demonstration of Site Remediation Technology

April 1994

- PROJECT SUMMARY -

PERVAPORATION OF VOLATILE ORGANIC COMPOUNDS FROM CONTAMINATED GROUNDWATER

ZENON ENVIRONMENTAL INC.
BURLINGTON, ONTARIO

INTRODUCTION

In 1989, the Canadian Council of Ministers of the Environment (CCME) acknowledged the need for a consistent national approach for the prioritization and remediation of high risk contaminated sites in Canada. In response to this need, CCME established the National Contaminated Sites Remediation Program (NCSRP), which is supported and administered through federal-provincial-territorial bilateral agreements.

The DESRT (Development and Demonstration of Site Remediation Technology) program is a component of NCSRP. It was established to address the NCSRP objective of working with industry to stimulate the development and demonstration of new and innovative technologies with the potential to resolve problems that are critical to the environmental remediation of contaminated sites.

An innovative technology selected for participation in the DESRT program was a cross-flow pervaporation process developed by Zenon Environmental Inc. A study using a pilot plant unit (built for the Emergencies Engineering Division of Environment Canada) was performed by Zenon in the summer of 1993, and was conducted with equal funding by the Ontario Ministry of Environment and Energy (MOEE) and Environment Canada under the DESRT program.

SITE HISTORY

The pilot-scale study was performed at a hydrocarbon contaminated site in southern Ontario.

DESRT SUPPORTED WORK

The program contributed approximately $480,000 to demonstrate and commercialize the pervaporation technology.

TECHNOLOGY DESCRIPTION

The Zenon pervaporation technology is designed to remove volatile organic compounds (VOC) from wastewater, leachate and contaminated groundwater. In the Zenon system, contaminated water is pumped into a pervaporation module containing a dense, organophilic membrane. The water flows across one side of the membrane, while the opposite side of the membrane is exposed to a vacuum (typically 760 mm of mercury). VOC in water diffuse through the membrane and are drawn off by the vacuum. Treated water is recovered or discharged. The VOC (and a small amount of water) passing through the membrane (permeate) are condensed and flow to a permeate collection tank where gravityseparation of water and VOC occurs. The concentrated VOC are recovered and the water is returned to the pervaporation system for further treatment.

TECHNOLOGY DEMONSTRATION SUMMARY

A four month pilot-scale study was performed to evaluate the Zenon pervaporation system. Several wells at the site were analyzed to identify the most contaminated source of groundwater. Water from the most contaminated well was then pumped to pervaporation system for treatment.

EVALUATION CRITERIA

A mass balance approach was used to evaluate the performance of the system. Water entering and leaving the system was analyzed to determine the amount of VOC removed during treatment. System performance was verified by the US EPA during eight hours of sampling and monitoring.

DEMONSTRATION RESULTS

Table 1 shows the results of the EPA sampling study. The Zenon pervaporation system removed more than 98% of the VOC (Benzene, Toluene, Ethylbenzene and Xylene) from the groundwater. Zenon claimed higher removals could be achieved by increasing the residence time in the system.

VOC removed by the system were highly concentrated allowing for waste minimization and the possibility of reclaiming the organic compounds. Exhaust from the vacuum pump was passed through a condenser before leaving the system, resulting in non-detectable VOC releases to the outside air.

STATUS

The information presented in this summary is based on a summary vendor's report. A technical report prepared by Zenon will be published under the DESRT program. A field demonstration of the pervaporation unit is scheduled to take place in 1994 under the Superfund Innovative Technologies Evaluation (SITE) Demonstration Program.

Project Summary prepared by the Wastewater Technology Centre for:
DESRT Program, Technology Development Directorate
Environmental Protection Service, Environment Canada
Hull, Quebec K1A 0H3

For Further Information Contact:
G. Hardy, Environment Canada (819) 953-0962
D. Vallery, Ministry of Environment and Energy (416) 323-4476

Table 1. Results of EPA Sampling Study for Untreated Groundwater and Water Treated by The Zenon Pervaporation Pilot-scale System

VOC	Untreated water (ug/L)[1]	Treated Water (ug/L)[1]	% Removal
Benzene	480	9	98.1
Toluene	340	6	98.2
Ethylbenzene	120	2	98.3
Total Xylenes	690	12	98.3
TOTAL VOC	1630	29	98.2

[1] Average concentrations of composite samples collected over an eight hour period.

DISCLAIMER/REVIEW NOTICE
This document has been reviewed by the Technology Development Directorate of Environment Canada. The contents do not necessarily reflect the views and policies of agencies represented by DESRT. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

Environment Environnement
Ontario

The National Contaminated Sites Remediation Program

DESRT Development and Demonstration of Site Remediation Technology

August 1994

- PROJECT SUMMARY -

A SELF-SEALING/SELF-HEALING WASTE CONTAINMENT SYSTEM

WASTEWATER TECHNOLOGY CENTRE

Burlington, Ontario

INTRODUCTION

In 1989, the Canadian Council of Ministers of the Environment (CCME) acknowledged the need for a consistent national approach for the prioritization and remediation of high risk contaminated sites in Canada. In response to this need, CCME established the National Contaminated Sites Remediation Program (NCSRP), which is supported and administered through federal-provincial-territorial bilateral agreements.

The DESRT (Development and Demonstration of Site Remediation Technology) program is a component of NCSRP. It was established to address the NCSRP objective of working with industry to stimulate the development and demonstration of new and innovative technologies with the potential to resolve problems that are critical to the environmental remediation of contaminated sites.

An innovative technology selected for participation in the DESRT program was a self-sealing/self-healing waste containment system. Researchers at Environment Canada's Wastewater Technology Centre (operated by RockCliffe Research Management) are cooperating with the Netherlands Energy Research Centre (ECN) to develop a novel proprietary barrier technology to isolate waste disposal sites from the environment.

DESRT SUPPORTED WORK

This project is being conducted to develop effective barrier formulations, and background data concerning the effectiveness of these formulations, at both laboratory and pilot scale. The project is equally funded by the Ontario Ministry of the Environment and Energy's (MOEE) and Environment Canada under the DESRT program. Total DESRT support is $ 344,606.

In continuing work, development of a customized barrier for the mining industry will be undertaken. Field demonstration of the barrier is being planned for the summer of 1995.

TECHNOLOGY APPLICATION

This new barrier technology will be useful in most applications involving containment of liquid pollutants, surface water or groundwater. Potential applications include: the mining industry, as a tailings site cover waste rock pile cover, or heap leach liner; in the chemical industry, as a liner for industrial sites; the hazardous industrial and/or municipal waste sectors, as a landfill liner or cover; as a surface impoundment liner for non-hazardous industrial waste; and site remediation for isolation of contaminated soils and sediments.

The barrier also has applications in transportation and construction, as a groundwater barrier for cuts, tunnels and subgrades, and in sealing of dams, foundations, artificial lakes, ponds, reservoirs, and spillways.

TECHNOLOGY DESCRIPTION

In general, a successful barrier system must satisfy three major criteria: 1) achieve low permeability to resist the movement of ground water and leachate, 2) act as a diffusive barrier in order to contain contaminants, and 3) maintain long term durability in the environment.

The Self-Sealing/Self-Healing (SS/SH) barrier concept offers unique advantages over existing technologies, and has the potential to satisfy the criteria for a successful landfill barrier system. The SS/SH barrier functions on the principle that two reactive parent materials, when placed in layers, will react at the interface to form an insoluble, highly impermeable seal. The primary advantage of this system, over conventional liners, is that unlike conventional barriers (which in the event of a breach in the liner it may be difficult to discover and if found, repair may entail an expensive excavation), any disruption of the impermeable layer of the SS/SH barrier will lead to new contact of the parents, and renewed formation of the seal. **Figure 1** Illustrates the SS/SH concept. Parents A and B react to form the highly insoluble products C and D. In the event of a breach, excess parent on both sides of the barrier will come into contact and react to "Self-Heal" the seal. **Figure 2** illustrates a healing scenario in which a breach due to settling has occurred.

TECHNOLOGY DEVELOPMENT SUMMARY

To date, four stages for the development of this technology have been conducted. The first stage was to asses the properties and characteristics of the various forms of generic parent materials that lead to successful seal formation and recommend feasible parent materials, in view of cost and reactivity, for continuing work. Solubility, homogeneity, purity, cost, and availability were important factors in selecting potential liner components. These factors were evaluated for a number of generic barrier parent materials, from North American suppliers, by subjecting them to laboratory testing.

The second stage of the work was conducted in order to develop a diffusion method to assist in examining a wide range of liner parameters in an efficient manner and allow the performance of the seal to be measured both qualitatively and quantitatively. Diffusion experiments were performed on single parent/matrix combinations alone, and compared to various parent/matrix combinations prepared for seal formation.

The third stage of the work dealt with the assessment of the hydraulic conductivity of various parent and parent/matrix combinations using a flexible wall permeameter. A flexible wall hydraulic conductivity testing method (ASTM D5084-90) was modified to measure the hydraulic conductivity of the barrier. In this method, external pressure is used to maintain contact between the flexible membrane and the sample to control side-wall leakage. Injection of dye into the inlet line prior to testing allowed visual observations of flow patterns to be made.

The most recent stage was carried out to determine the extent to which design parameters can be controlled to optimize the performance of the barrier. The goal in optimization of the SS/SH barrier was to minimize costs, while maximizing performance. A number of preliminary experiments were first conducted to gain familiarity with barrier placement techniques, and to identify which factors most influenced barrier performance. Following this, an optimization experiment was initiated, employing a Half-Fraction Factorial Design Experiment, designed to isolate the most influential barrier design parameters. Two additional seal formation experiments were performed using magnesite as the magnesium carbonate parent.

TECHNOLOGY DEVELOPMENT RESULTS

The parents were found to exist in a variety of forms, differing in terms of components, purity, and cost. Two inexpensive reagent grade materials emerged as feasible parents : Magnesite ($MgCO_3$) as the magnesium carbonate parent, and High Calcium Hydrated Lime, as the calcium hydroxide parent.

Following the diffusion studies, the diffusion coefficient was found to vary between 0.9 to 1.5 E-0.6 cm^2/s. By comparing diffusion profiles of the magnesite and seal profiles, the diffusive resistance of the seal is evident.

Only limited success was obtained using a flexible wall permeameter to measure hydraulic conductivity, as significant side-wall leakage was observed. Dye testing , however, was able to show flow of permeant around, rather than through the interface between parents.

The results of the optimization experiments indicate that the most influential parameter, exclusive of solubility, was bulk parent concentration. The solubility of the parents have a pronounced effect on seal formation. Non-stoichiometric parent concentrations in solution lead to a shift in the precipitation zone, and may result in weak seals, or increase the time required for self-healing. Seals formed using magnesite performed well, under various testing scenarios. Tracer was completely contained above the interface, or was significantly impeded by the resulting seal. Reseal experiments were conducted on these samples by puncturing the seals after tracer addition. After an initial progression of tracer, the barrier was seen to re-heal, and again impede the diffusion of tracer.

STATUS

In continuing work, development of a customized barrier for the mining industry will be undertaken. Field demonstration of the barrier is being planned for the summer of 1995.

Project Summary prepared by Wastewater Technology Centre for:
DESRT Program, Technology Development Directorate
Environmental Protection Service, Environment Canada
Hull, Quebec K1A 0H3

In cooperation with:
Ontario Ministry of the Environment and Energy
Environmental Technologies Program

For Further Information Contact:
L. Keller, Environment Canada (819) 953-0962
J. Stegemann, Wastewater Technology Centre (905) 336-4738

Figure 1

Self-Sealing/Self-Healing Barrier Concept

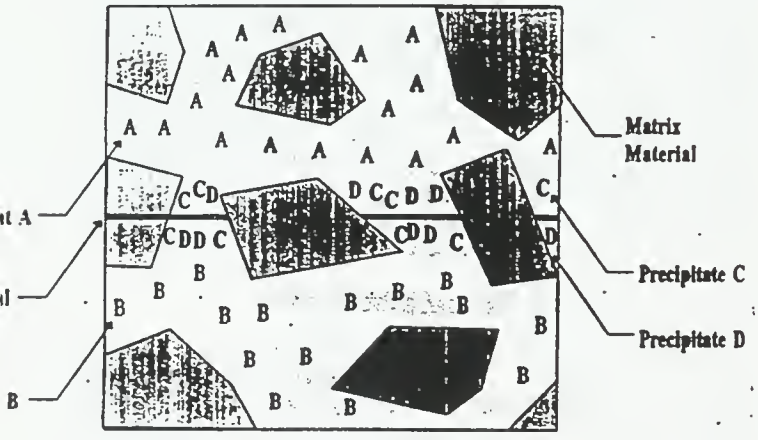
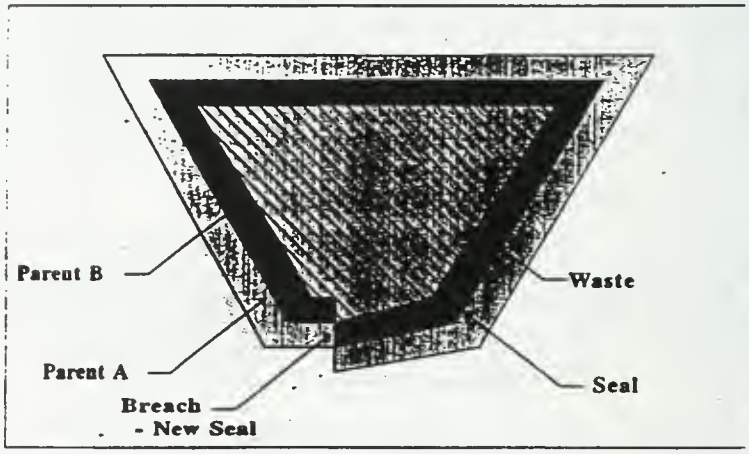


Figure 2

Self-Healing Mechanism



DISCLAIMER/REVIEW NOTICE
This document has been reviewed by the Technology Development Directorate of Environment Canada. The contents do not necessarily reflect the views and policies of agencies represented by DESRT. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

The National Contaminated Sites Remediation Program

DESRT Development and Demonstration of Site Remediation Technology

PERFORMANCE TESTS OF THE TRIWASTE MOBILE THERMAL PHASE SEPARATOR

TriWaste Reduction Services, Calgary, Alberta

August, 1995

INTRODUCTION

In 1989, the Canadian Council of Ministers of the Environment (CCME) acknowledged the need for a consistent national approach for the prioritization and remediation of high risk contaminated sites in Canada. In response to this need, CCME established the National Contaminated Sites Remediation Program (NCSRP), which is supported and administered through federal-provincial-territorial bilateral agreements.

The Development and Demonstration of Site Remediation Technology (DESRT) program is a component of NCSRP. It was established to address the NCSRP objective of working with industry to stimulate the development and demonstration of new and innovative technologies with the potential to resolve problems that are critical to the environmental remediation of contaminated sites.

An innovative technology selected for participation in the DESRT program was TriWaste's Mobile Thermal Phase Separator. A full scale study of the technology was performed by TriWaste Reduction Services and was jointly funded by Environment Canada, the Newfoundland Department of Environment, and the vendor.

SITE HISTORY

SCC Environmental of St. John's, Newfoundland, and TriWaste Reduction Services Inc. of Calgary, Alberta, were awarded a contract to remediate 1200 m^3 of PCB contaminated soil at the Makinsons site, Newfoundland. The orphaned site, currently under the jurisdiction of the NCSRP, was previously used as a metal salvage yard and is located 85 kilometers west of St. John's, Newfoundland. Between 1965 and 1985, operations at the salvage yard focused on the recovery of copper wire from insulated electrical wire and electrical transformers. Some of the transformers contained mineral oil with low concentrations of PCBs. The process at the yard involved draining the oil from the transformers, on the ground, burning the oil and extracting the core from the metal casings.

DESRT SUPPORTED WORK

Some of the concerns associated with the use of thermal desorption technologies for the remediation of PCB contaminated soils include PCB removal efficiency and the production of dioxins and furans. Thermal Phase Separation technology has been used for remediating soils with chlorophenols and dichlorobenzenes but has not yet been proven to remediate soils containing PCBs. For this reason the DESRT program supported the performance of full scale tests of TriWaste's Mobile Thermal Phase Separator (Model TPS-1). These tests, conducted in Alberta and Newfoundland, were geared to evaluate the technology's effectiveness in remediating PCB contaminated soil while complying with federal and provincial requirements for emissions. The DESRT program contributed $51,000.00 toward the total cost of $180,000.00. The remaining $80,000.00 was contributed by TriWaste Reduction Services.

TECHNOLOGY DESCRIPTION

TriWaste's Model TPS-1 uses indirect heating to separate hydrocarbon contaminants from the soil. It can be used to remove chlorinated or non chlorinated hydrocarbons with boiling points of up to 600°C. The Model TPS-1 is not an incineration process and therefore should not produce products of incomplete combustion.

In the operation of the first stage of this two stage process the contaminated soil is augured through the extraction chamber and is indirectly heated to 650 °C, thereby volatilizing the hydrocarbon contaminants (See Figure 1).

The second stage then cools the off gases from the extraction chamber that contain the contaminants. The cooling process condenses the contaminants into a liquid which is then separated into oil and water fractions. The remaining relatively dry gas stream of non-condensable gases is subjected to final polishing in a mist eliminator and a series of carbon adsorption beds. This gas stream is fed into the firebox as fuel to heat the extraction chamber.

PERFORMANCE TEST RESULTS

In order to demonstrate that the Model TPS-1 could remediate PCB contaminated soils while maintaining compliance with federal and provincial emission requirements, a series of stack emission tests were performed. The stack gas was monitored for the presence of PCBs, products of incomplete combustion, particulates, and HCl. The emission of dioxins and furans were also measured.

The sampling protocols used in these tests were based on *Sampling Method - Environment Canada Reference Method (EPS 1/RM/2)*. The first set of triplicate tests was conducted in Alberta in July, 1994, on soils containing an average PCB concentration of 283 mg/kg. Although the tests results demonstrated that TriWaste's Model TPS-1 was able to meet both air and soil regulatory limits for dioxins/furans, HCl, and particulate emissions, the high variability in the concentrations of PCBs in the feed soils required that a second set of triplicate tests be conducted for PCBs only.

This second set of triplicate tests was conducted at the Makinsons site in Newfoundland in October, 1994, and confirmed the ability of the Model TPS-1 technology to meet regulatory requirements for the treatment of PCB contaminated soils. Table 1 summarizes the results from the performance test programs.

The destruction and removal efficiency (DRE) is defined as the mass ratio $(PCB_{IN}-PCB_{OUT})/PCB_{IN}$. The standards for PCBs is 99.9999% (six 9s) removal. This DRE was achieved by the Model TPS-1. Furthermore, the dioxin and furan levels were rigorously tested and found to be 930 times lower than the levels stipulated in the regulations. The removal efficiency of the Model TPS-1 for PCBs and dioxins/furans in soil exceeded 99.9% and 80.0% respectively. The Model TPS-1 proved to be capable of meeting the CCME Residential/Parkland clean-up criterion for PCBs of 5 mg/kg on a dry soil basis.

CONCLUSIONS

The performance tests conducted under the DESRT program have demonstrated that TriWaste's Model TPS-1 is capable of processing PCB contaminated soil at a rate of more than 4 tonnes/hr while complying with federal and provincial emission requirements for PCBs, dioxins/furans, HCl, and particulates.

The DESRT performance tests have clearly demonstrated that the PCBs and dioxins/furans emitted by TriWaste's Model TPS-1 are insignificant, even when compared to the project criteria.

The contaminant volume reduction achieved by the Model TPS-1 significantly minimizes the amount of contaminated material which eventually has to be destroyed through a costly incineration process. Substantial cost savings can be achieved by this reduction in contaminated material.

STATUS

The field demonstration is now completed and a final report is currently undergoing review. As a result of the demonstration, TriWaste has designed and fabricated another mobile unit (Model TPS-2) which has double the capacity of the TPS-1 with only a 30% increase in footprint.

FOR FURTHER INFORMATION

For further information, please contact:

Ken Dominie, Newfoundland Dept. of Environment
(709) 729-2256

Lisa Keller, Environment Canada
(819) 953-0962

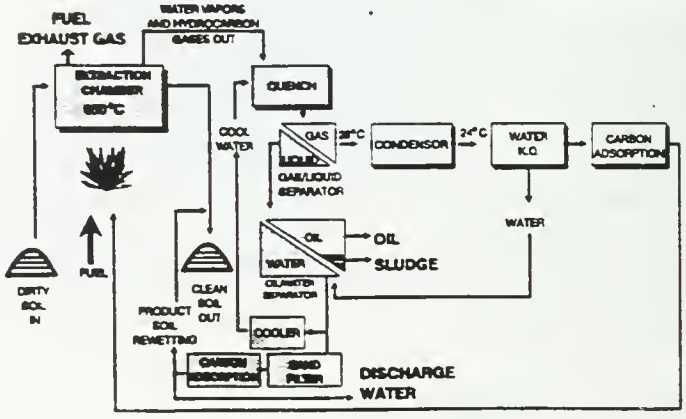
Jacques Benoit, TriWaste Reduction Services Inc.
1-800-563-4242

Table1: Results from the Performance Tests

Parameter	3 Test Average Cremona	3 Test Average Makinsons	Test Criteria
FEED SOILS			
Feed Rate (tonnes/hr) dry	1.060	4.432	
Soil Moisture Content %	10.7	12.5	
PCB Content (mg/kg) dry	283.3	148	
Inlet Mass Loading (kg/hr)	0.2988	0.6551	
Dioxins and Furans (as TEQ) (µg/kg)	0.0153	NM	
TREATED SOILS			
PCB (mg/kg) wet	1.7	0.058	<5
PCB Removal Efficiency (%)	>99.4	>99.96	
Dioxins and Furans (as TEQ) (µg/kg)	0.003	NM	<1
Dioxins and Furans (as TEQ) Removal	>80.0	NM	
STACK GAS EMISSIONS			
PCB Concentrations mg/(Nm^3) c/o 11% O_2	0.12746	0.00013	
Stack Gas Mass PCB Loading (mg/hr)	0.2479	0.3758	
Ratio of Inlet Mass Loading to Stack Gas	0.8858	0.5721	<1.0
HCl (mg/Rm^3)	<0.002	NM	75
Particulate (mg/Rm^3)	14.28	NM	200
Dioxins and Furans (ng/Rm^3)	0.01297	NM	12
PCB Destruction Removal Efficiency (%)	>99.9999	>99.9999	99.9999

TEQ: Toxicity Equivalence, R: Reference, NM: Not Measured

Figure 1: Flow Diagram- Thermal Phase Separator



DISCLAIMER/REVIEW NOTICE

This document has been reviewed by the Technology Development Directorate of Environment Canada. The contents do not necessarily reflect the views and policies of agencies represented by DESRT. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

GOVERNMENT OF NEWFOUNDLAND AND LABRADOR

Canada

Environment Canada Environnement Canada

The National Contaminated Sites Remediation Program

DESRT Development and Demonstration of Site Remediation Technology

GRAVEL WASHING PROJECT - CANADA CREOSOTE SITE
ALBERTA RESEARCH COUNCIL/ACRES INTERNATIONAL LTD.
CALGARY, ALBERTA

- PROJECT SUMMARY -

DECEMBER 1993

INTRODUCTION

In 1989, the Canadian Council of Ministers of the Environment (CCME) acknowledged the need for a consistent national approach for the prioritization and remediation of high risk contaminated sites in Canada. In response to this need, CCME established the National Contaminated Sites Remediation Program (NCSRP), which is supported and administered through federal-provincial-territorial bilateral agreements.

The DESRT (Development and Demonstration of Site Remediation Technology) program is a component of the NCSRP, and was established to address the NCSRP objective to work with industry to stimulate the development and demonstration of new and innovative technologies having the potential to resolve problems which are critical to the environmental remediation of contaminated sites.

A technology selected for participation in the DESRT Program was a gravel washing system developed by the Alberta Research Council. The study was conducted by the Alberta Research Council in coordination with Acres International Ltd., and was jointly funded by Environment Canada, Alberta Environment, and the vendors.

SITE HISTORY

The Canada Creosote site is located near downtown Calgary along the south side of the Bow River. Wood preserving operations were carried out at the site from the mid 1920s to mid 1960s. During the course of these operations, large quantities of creosote and pentachlorophenol were spilled at the site. Creosote in the form of a dense non-aqueous phase liquid (DNAPL) has been found underlying the site and has migrated into the river bed gravels and the north bank of the Bow River. Studies are currently being carried out to determine the nature, extent and behaviour of the creosote pool.

DESRT SUPPORTED WORK

The DESRT program supported a pilot program study at the Canada Creosote site to investigate alternative remediation techniques for creosote contaminated sub-river gravels. This study included cofferdam construction, gravel washing, water treatment and sludge treatment. The DESRT program has contributed $2,043,000 to studies carried out at the Canada Creosote site.

TECHNOLOGY DESCRIPTION

The gravel washing technology used by the Alberta Research Council consisted of a screening process, passing the material through a coarse material screw and/or fine material screw, and a tumbler/trommel. The process is optimized based on temperature and residence time in the tumbler.

TECHNOLOGY DEMONSTRATION SUMMARY

In order to facilitate excavation of contaminated riverbed gravels, a cofferdam 35 metres long and 25 metres wide was built within an existing berm in the river. The cofferdam consisted of three trial sections (a pervious fill berm, a pre-cast concrete cell, and a driven sheet-pile cell). After cofferdam construction, a one-metre wide impervious bentonite slurry wall cut-off was installed around the perimeter of the cofferdam.

Contaminated river gravels were excavated from the cofferdam using a back-hoe loader combination and fed into a 200 mm grizzly to remove boulder-sized stones. The gravels were then passed along a conveyor to a vibrating 3-deck screen where they were washed and processed into three fraction: 200 x 75 mm, 75 x 3 mm, and 3 x 0 mm. The 200 x 75 mm fraction was stockpiled without further washing. The 75 x 3 mm fraction was transferred via gravity chute to a coarse material screw. The 3 x 0 mm fraction was gravity fed with wash water to a fine material screw where washing and dewatering occurred. Following treatment, this fraction was stored as a hazardous waste.

Tests were conducted using a tumbler/trommel to clean the 75 x 3 mm fraction. Thirteen gravel washing and rewashing tests were performed using different combinations of equipment, water quantity and quality, and feedstock material.

The average rate of gravel washing was 50 tonnes per day with a maximum of 3000 tonnes per day. The total quantity of contaminated gravel excavated and treated was 1000 tonnes and, of this, 100 tonnes was rewashed.

In addition to the material separated and washed through the gravel washing plant, a significant amount of fine sludge accumulated in settlement tanks and within the cofferdam excavation area. This material was removed and eventually passed through a centrifuge to reduce the water content.

Most of the creosote found throughout the pilot program

study was associated with the dewater sludge and the 3 x 0 mm fine sand generated from the gravel washing operation. All of the waste water generated during gravel washing was treated on site and recycled. The treatment train for wastewater generated included five dirty water/settling tanks, clarifier, bag filter, Kiensorb column, granular activated carbon column, and three semi-clean and two clean water storage tanks.

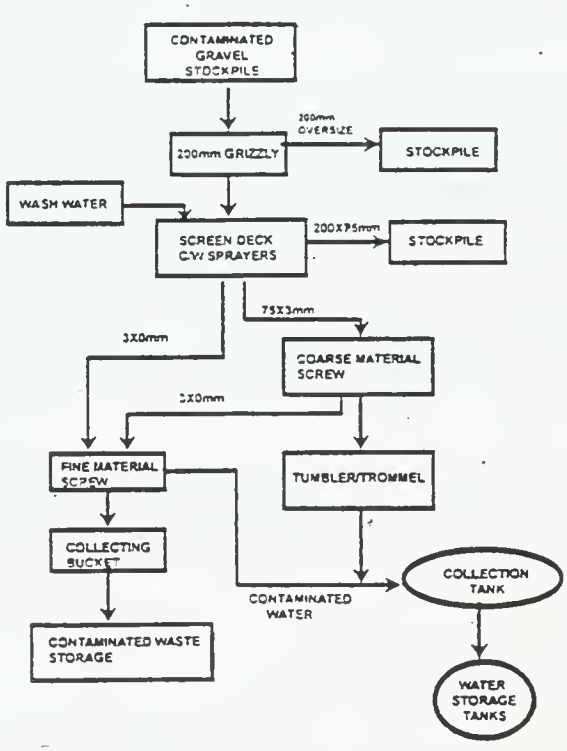
DEMONSTRATION RESULTS

When washed with clean or semi-clean water on the vibrating screen deck, the riverbed gravels were reported to have been adequately cleaned. Based on the results, it is expected that washed gravel would be suitable for return to the river.

The 200 x 75 mm fraction was clean of silt and creosote and had virtually no odour. The 75 x 3 mm stock pile was also free of silt and occasionally had a very slight creosote odour. The 3 x 0 mm fines were typically saturated with water and had a strong creosote odour.

The use of water jets dislodged the sticky sand and fines from pebble surfaces. This process appeared to be more efficient when contaminated gravel was tumbled with water. The range of DNAPL content on the cleaned pebbles, of greater than 1 mm size, is 0.08-0.04% by weight, and on cleaned pebbles less than 1 mm in size the DNAPL content was 7.0-0.5% by weight.

Figure 1 - Gravel Washing Schematic Diagram



Washing with recycled, or "dirty water", appeared to clean the fines and silt from the rock but was ineffective in removing the creosote. The washed gravels were typically coated with a sheen and possessed a strong creosote odour.

Additionally, washing with "dirty water" increased the level of suspended fines in the wash water which made water treatment more difficult.

Rinsing washed gravel in the trommel with warm water (60°-80°C) was reported to provide an effective second cleaning. The warm water caused steam with a strong creosote odour near the trommel, and after rinsing, the gravels carried virtually no odour. The trommel was ineffective as a stand alone unit for processing raw contaminated gravels from the cofferdam.

The waste stream from the gravel washing process consists of DNAPL and fine sands and soil which separate into water and organic phases. The clear water phase contained total organic carbon varying between 4-18 ppm depending on washing treatment. Approximately 45-50 minutes settling time was required for phase separation.

Approximately 1950 m^3 of sludge was generated on site during the excavation and gravel washing operations. After centrifugation the dewater sludges were gravity fed into a skid steer loader bucket and transported to storage bins.

STATUS

The gravel washing pilot program was completed in the fall of 1991. A final report has been approved and is available

Project Summary prepared by Wastewater Technology Centre for:
DESRT Program, Technology Development Directorate
Environmental Protection Service, Environment Canada
Hull, Quebec

In cooperation with:
Alberta Environment (HELP Project)

For Further Information Contact:
G. Hardy, Environment Canada (819) 953-0962
W. Cerioci, Alberta Environment (403) 427-6181

Table 1. - Analysis of Waste Water

Water Sample	Total Organic Carbon (mg/l)	Phenol (mg/l)
A. Lab Tumbling Test (B#16)	5.8	0.073
B. Tails Water, IATF Run 2 without coal	17.4	-
C. Tails Water, IATF Run 2 with coal	12.7	-
D. Once-cleaned gravel (% DNAPL = 0.02) - tumbled with fresh tap water	4.0	0.037
Tap Water	1.2	

DISCLAIMER/REVIEW NOTICE

This document has been reviewed by the Technology Development Directorate of Environment Canada. The contents do not necessarily reflect the views and policies of agencies represented by DESRT. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

Environment Environnement

Alberta
GOVERNMENT OF ALBERTA

The National Contaminated Sites Remediation Program

DESRT Development and Demonstration of Site Remediation Technology

INTEGRATION OF ENHANCED OXIDATION AND SONIC MIXING FOR THE TREATMENT OF CONTAMINATED SOIL

ARC SONICS INC., BURNABY, BRITISH COLUMBIA

• PROJECT SUMMARY •

July 1995

INTRODUCTION

In 1989, the Canadian Council of Ministers of the Environment (CCME) acknowledged the need for a consistent - national approach for the prioritization and remediation of high risk contaminated sites in Canada. In response to this need, CCME established the National Contaminated Sites Remediation Program (NCSRP), which is supported and administered through federal-territorial bilateral agreements.

The DESRT (Development and Demonstration of Site Remediation Technology) program is a component of NCSRP. It was established to address the NCSRP objective of working with industry to stimulate the development and demonstration of new and innovative technologies with the potential to resolve problems that are critical to the environmental remediation of contaminated sites.

DESRT SUPPORTED TECHNOLOGY

ARC Sonics Inc. of Burnaby, B.C., with the assistance of the Emergencies Engineering Division (EED) of Environment Canada, investigated the effectiveness of combining an advanced oxidation process with a new sonic mixing technology for the destruction of organic contaminants in soils. The ultraviolet light used in this work was provided by Solarchem Environment Systems Ltd. of Markham, Ontario.

Equipment Description

The equipment used in this work is ARC Sonics' patented Sonic Grinder. The main component is a massive steel bar which is vibrated at its lowest resonant frequency of 100 hz by large electromagnets. Sono-reaction chambers mounted on the ends of the bar are subjected to accelerations of several hundred times that of gravity, thus creating intense acoustic pressure waves and cavitation in a fluid or slurry in the chamber. The equipment, which produces power levels up to 50 kW in a 2 to 7 litre chamber, is designed to operate either in batch or continuous mode.

Sonic Pressure Waves and Cavitation

In this application, the sonic reactor is used to apply sonic energy to agglomerated soils, such as clays. One physical effect of the intense sonic pressure waves and cavitation on these soils can be to deagglomerate them and disperse the particles uniformly through the slurry. Grinding media, in the form of small ceramic grinding balls, can be added to the chamber to enhance deagglomeration.

Advanced Oxidation

Advanced oxidation technologies have been found to be effective methods of destroying contaminants in water. Often ultraviolet (UV) light is combined with oxidants, such as hydrogen peroxide or ozone, to produce hydroxyl radicals. The hydroxyl radical reacts very rapidly with most organic compounds, converting them to carbon dioxide and water (and hydrochloric acid in the case of chlorinated hydrocarbons). However, treatment technologies utilizing UV light oxidation technologies are limited to the treatment of contaminated water because of their inability to treat soil slurries containing agglomerated lumps with encapsulated contaminants, and the inability of the UV to penetrate into the slurry.

High-intensity sound waves in a fluid produce transient acoustic cavitation, that is, the generation, growth, and collapse of gas-filled bubbles. During bubble collapse, local temperatures as high as 10,000 deg C and pressures as high as 4,000 atmospheres have been reported in the literature. These conditions are capable of producing hydroxyl radicals, either from the water alone, or from aqueous solutions of oxidants such as ozone and hydrogen peroxide.

ARC Sonics' work has shown that intense sonic energy, in combination with ozone, is a powerful system for oxidizing organic compounds, as discussed in the next section.

PROJECT DEMONSTRATION SUMMARY

Phase 1 of the project involved variations of a treatment process using clay soils spiked with xylene, perchloroethylene, phenol or pentachlorophenol (PCP). The most promising of the three processes was repeated in phase 2 with soil samples from actual chemical spill sites.

1. Sonic Energy/UV/H_2O_2 Treatment Process -

The soil was dispersed into a slurry using sonic energy alone, or (when necessary) by sonic grinding. The slurry was then placed in the sono-reactor, a stainless steel chamber, one side of which featured a quartz window. Hydrogen peroxide, equal in weight to the contaminant in the clay, was added immediately before sealing the sono-reactor and mounted on the sonic grinder. Sonic energy provided the mixing, while UV energy was transmitted to the slurry through the quartz window. A parametric study involving various treatment times and sonic power levels was conducted.

2. Sonic Energy/H_2O_2 Treatment Process -

Since the optimization tests for process 1 indicated that contaminant destruction appeared to be taking place during the dispersion phase, process 2 tests focussed on the destruction of PCP and PCE with and without grinding media, the addition of H_2O_2 and variations in power levels and treatment times.

3. Sonic Energy/Ozone Treatment Process -

In view of the relatively low destruction rates achieved in the first two processes, it was decided to pursue the sonic dispersion process using ozone as the oxidant. The ozone gas stream was 3% O_3 and 97% O_2. It was produced by an ozone generator and injected directly into the slurry as it was subjected to high-intensity sonic energy. A parametric study involving treatment times, contaminant type and level, power level, and the use of grinding media was conducted. This process was repeated for phase 2 of the project.

TECHNOLOGY DEMONSTRATION RESULTS

Analysis of the samples was conducted by Analytical Services Laboratory (ASL) of Vancouver using established EPA analytical methods (Gas Chromatography). The Emergencies Engineering Division of Environment Canada in Ottawa conduced analyses on 10 to 20% of the samples as a quality control measure.

The main findings of this study are:

Sonic treatment, and (when necessary) sonic grinding, of clay or silty soils is fast and effective in reducing the soil to a uniform slurry with particles in the 1 to 20 micron size range. This slurrying step is very effective in preparing agglomerated contaminated soil for treatment.

A comparison of three sonic power levels (5, 7.5 and 10kW) indicated that 7.5 kW provided the optimum destruction rates.

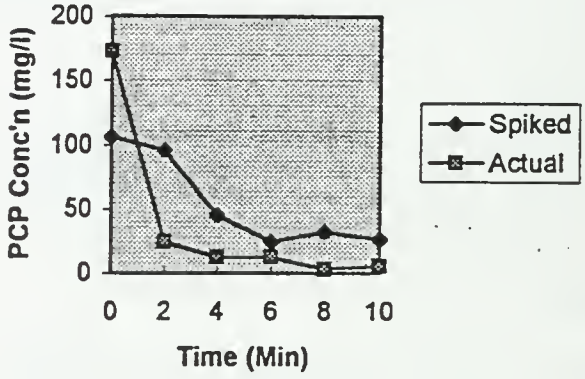
The combination of Sonic Energy/UV/H_2O_2 resulted in destruction of the contaminants in question, however, destruction rates were too low to warrant further investigation. It is believed that despite the sonic mixing, the opacity of the slurry did not allow UV light to penetrate the sample. Extended treatment times of up to 15 min, did not significantly improve these results.

In the second treatment process, which involved adding hydrogen peroxide during the dispersion/grinding process, significant destruction of both PCE and PCP was obtained, however, the destruction rates were still modest.

Of the three processes, the combination of ozone and sonic energy appeared to provide the best results for destroying PCP in both spiked and actual spill samples. Results of these two tests are displayed in Figure 1. In both cases the ozone addition and sonic power were held at 359mg/min and 5kW respectively.

During the destruction of PCP, the pH tended to fall due to the suspected release of chlorine ions. When starting with soils spiked with PCP to high levels (>1000 ppm), destruction slowed markedly in the 100 ppm range, possibly due to the formation of intermediates which reacted with the available oxidant therefore acting as scavengers.

Figure 1: PCP Destruction in the Presence of Ozone and Sonic Agitation



STATUS

The sonic dispersion/grinding process has been found to be very effective in deagglomerating soils, which allows encapsulated contaminants to be treated. The sonic process, in combination with ozone as the oxidant, appears to be very effective on the destruction of PCE, PCP and BTEX. A final report has been submitted and reviewed.

FOR MORE INFORMATION

The project was carried out by ARC Sonics Inc. in collaboration with The Emergencies Engineering Division of Environment Canada. The information provided in this summary is based on an interim technical report produced in December 1994.

For more information, please contact:

L. Keller, DESRT Program, (819) 953-0962

J. Ward, BC Ministry of Environment, Lands and Parks
(604) 387-9951

D.Warren, ARC Sonics Inc. (604) 990-1391

DISCLAIMER/REVIEW NOTICE

This document has been reviewed by the Technology Development Directorate of Environment Canada. The contents do not necessarily reflect the views and policies of agencies represented by DESRT. Mention of trade names or commercial products does not constitute a recommendation or endorsement for use.

The National Contaminated Sites Remediation Program

DESRT Development and Demonstration of Site Remediation Technology

FEASIBILITY STUDY OF BIOREMEDIATION OF THE PEERLESS WOOD PRESERVERS SITE

ALBERTA RESEARCH COUNCIL
Edmonton, Alberta

- PROJECT SUMMARY -

AUGUST 1994

INTRODUCTION

In 1989, the Canadian Council of Ministers of the Environment (CCME) acknowledged the need for a consistent national approach for the prioritization and remediation of high risk contaminated sites in Canada. In response to this need, CCME established the National Contaminated Sites Remediation Program (NCSRP), which is supported and administered through federal-provincial-territorial bilateral agreements.

The DESRT (Development and Demonstration of Site Remediation Technology) program is a component of the NCSRP, and was established to address the NCSRP objective to work with industry to stimulate the development and demonstration of new and innovative technologies having the potential to resolve problems which are critical to the environmental remediation of contaminated sites.

A research project selected for participation in the DESRT program was a bioremediation feasibility study conducted by the Alberta Research Council. The study was jointly funded by Environment Canada, and the Alberta Environment under the DESRT program.

SITE HISTORY

The Peerless Wood Preservers site is located near Cayley, Alberta, approximately 60 km south of Calgary. From 1958 until 1982, the site was used for the pressure treatment of wood products using pentachlorophenol (PCP). The site was abandoned in 1982. A site assessment carried out between 1989 and 1990 indicated contamination at the site covering an area of about 7200 m^2 and extending in some places to depths in excess of 3 metres. The primary contaminants of concern are process residues from the wood preserving operation, principally PCP.

DESRT SUPPORTED WORK

The DESRT program supported a laboratory scale treatability study for bioremediation of the Peerless site, conducted by the Alberta Research Council. The objective of the study was to determine if contaminants at the site were amenable to biodegradation by the indigenous microbial population, over a range of concentration and temperature conditions.

The treatability study was conducted over the spring of 1991. DESRT supported costs for this project totalled $93,000 (1991/92).

TECHNOLOGY DESCRIPTION

The Alberta Research Council conducted the feasibility study by examining biodegradation by the indigenous microbial population. Microbial population growth was encouraged in the laboratory scale study through aeration and the addition of nutrients (NH_4NO_3 and $(NH_4)_3PO_4$). Plate counts determined the total number of microorganisms and the number of microorganisms "acclimated" to elevated levels of PCP.

TREATABILITY STUDY SUMMARY

Soil samples were collected from nine locations within the site on February 13, 1991. The samples were characterized for several parameters, including oil and grease and PCP. Based on these analyses, three soils containing low (300 ppm), medium (500 ppm) and high (900 ppm) levels of PCP were selected for treatment.

Treatment consisted of placing 250 grams (dry weight) of each soil in a 2 L mason jar, adjusting the moisture contents of the soils to 70% of field capacity and adding nutrients (nitrogen and phosphorus). Soils were aerated, by mixing, on a weekly basis.

Biodegradation of contaminants in the treated soils (low, medium and high) was determined at a temperature of 15°C and also at 5°C and 25°C for soil containing the medium level of PCP contamination.

TREATABILITY STUDY RESULTS

The investigators concluded that contaminants in the soils from the Peerless site were amenable to biodegradation by the indigenous microorganisms. PCP concentrations (Figure 1), oil and grease levels (Figure 2) and the toxicity of the soils (Figure 3) were apparently reduced over a 20 week period. Carbon dioxide evolution and the total number of microorganisms in the soil also changed with time.

Temperature and PCP concentration influenced contaminant degradation, with low temperatures and high PCP concentrations having an adverse effect on biodegradation. As a results, the authors recommended extending the study to see how far PCP degradation would proceed and thereby determine the residual levels of contamination in the soils.

STATUS

The study was completed in the summer of 1992. A draft final report was prepared and approved.

As a result of this treatability study, a bioremediation field pilot experiment at the Peerless Wood Preserves has been initiated. Results obtained after one year of operation indicate that most PCP concentrations would meet CCME soil remediation criteria after the two year operation period, while additional soil remediation may be required after the two year operation period for oil and grease concentrations to meet CCME criteria.

Project Summary prepared by Wastewater Technology Centre for:
DESRT Program, Technology Development Directorate
Environmental Protection Service, Environment Canada
Hull, Quebec

In cooperation with:
Alberta Environment (HELP Project)

For Further Information Contact:
M. Trudell, Alberta Research Council (403) 438-7506
L. Keller, Environment Canada (819) 953-09628

FIGURE 1. Effect of Treatment on PCP concentrations. Legend scheme: Treatment concentration (Low, Moderate, High); Treatment temperature in °C (5,15, or 25).

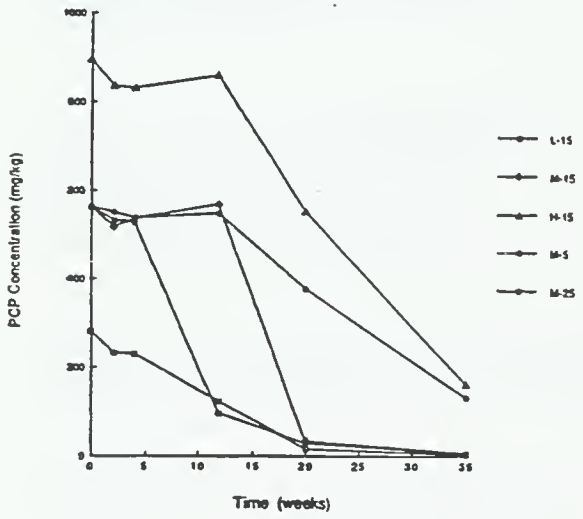


FIGURE 2. Effect of treatments on oil and grease concentrations. Legend scheme: Treatment concentration (Low, Moderate, High); Treatment temperature in °C (5,15, or 25).

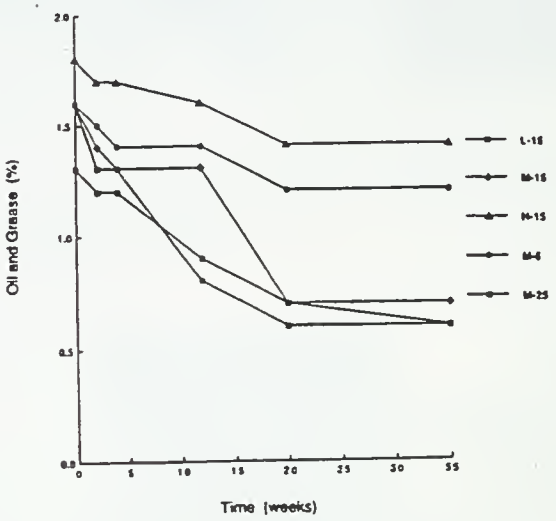
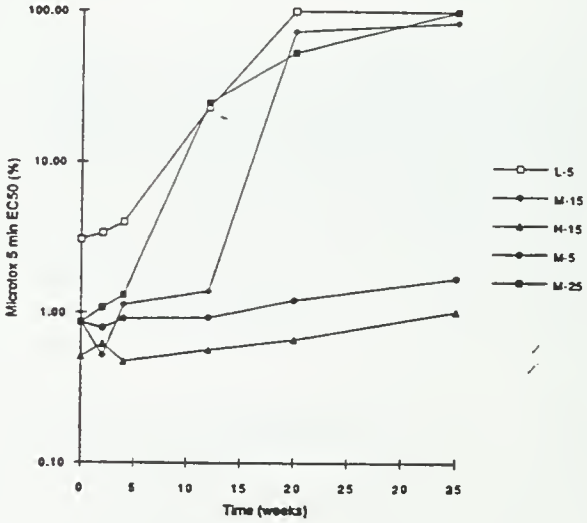


FIGURE 3. Effect of treatments on oil toxicity (Microtox); 5-minute EC_{50} concentration (% soil solution extract). Legend scheme: Treatment concentration (Low, Moderate, High); Treatment temperature in °C (5,15, or 25).



DISCLAIMER/REVIEW NOTICE
This document has been reviewed by the Technology Development Directorate of Environment Canada. The contents do not necessarily reflect the views and policies of agencies represented by DESRT. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

The National Contaminated Sites Remediation Program

DESRT Development and Demonstration of Site Remediation Technology

THE BIO-REACTOR PROJECT: THE REMEDIATION OF HYDROCARBON AND BRINE CONTAMINATED TOPSOIL

Nevis, Alberta

- PROJECT SUMMARY-

June 1995

INTRODUCTION

In 1989, the Canadian Council of Ministers of the Environment (CCME) acknowledged the need for a consistent national approach for the prioritization and remediation of high risk contaminated sites in Canada. In response to this need, CCME established the National Contaminated Sites Remediation Program (NCSRP), which is supported and administered through federal-provincial-territorial bilateral agreements.

The DESRT (Development and Demonstration of Site Remediation Technology) program is a component of the NCSRP, and was established to address the NCSRP objective to work with industry to stimulate the development and demonstration of new and innovative technologies having the potential to resolve problems which are critical to the environmental remediation of contaminated sites.

DESRT SUPPORTED TECHNOLOGY

The project involved the research and field testing of a near commercial scale Bio-Reactor designed to treat large volumes of soils and soil-like materials contaminated with hydrocarbons, salts and metals.

The DESRT Program has supported the Bio-Reactor Project between 1992 and 1994, co-funding the study with GASReP and PERD (Environment Canada), Alberta Environmental Research Trust (AERT), the Canadian Association of Petroleum Producers (CAPP) and the Canadian Petroleum Products Institute (CPPI). A total of $2.15M in funding was provided to the project, between 1991 and 1994, by the various supporters.

Support has continued from the planning and design stages through laboratory testing on waste structure stabilization, salt removal and biodegradation and engineering, construction and operation of experimental field facilities. The requirements of the technology were (1) to form wastes into water stable soil-like aggregates, (2) removal of salts by leaching and down-well disposal, (3) definition of the optimal conditions for biodegradation of hydrocarbons, (4) development of a field facility with controls for maintaining above-ambient temperatures, irrigation, forced subsurface aeration, precision tillage, leachate collection, and (5) establishment of treatment endpoints utilizing chemical, physical and ecotoxicological criteria.

It is important to note that the Bio-Reactor was designed as a unit in which to conduct medium scale (4-8 tonne/treatment) experiments. As an experimental unit, it was engineered to exert environmental controls on replicated cells and to permit statistically sound sampling of the waste, air emissions and leachates. Thus the economics of treating wastes in the Bio-Reactor are not comparable to commercial operations but costs can be estimated once the best protocol is established.

CONTAMINATION CHARACTERISTICS

The first of three wastes to be remediated by the solid-phase Bio-Reactor process was an agricultural topsoil contaminated with crude oil and brine as a result of a pipeline break in central Alberta. The soil contained 4% organic matter, 34% clay, 27% silt and had a pH of 8.1 and a calcium carbonate equivalent of 2.4%. The contaminated soil contained 43,000 mg/kg of oil and had an EC (electrical conductivity) of 27 dS m^{-1} and was severely water repellent. It was essential to remove the salts (NaCl) prior to initiating the biological process necessary to reduce the hydrocarbons.

TREATABILITY STUDY SUMMARY

Laboratory studies on the physical properties of the contaminated soil resulted in a procedure to aggregate the waste into a soil-like material. High speed mixing of the waste with lime, straw and starch resulted in a matrix with a stable system of macropores that would permit rapid salt leaching and subsequent efficient water and gas exchange; essential properties for bioremediation.

Environmental factors affecting the microbial degradation were studied on small aggregated samples in a laboratory setting; replicated treatments being evaluated using measurements of hydrocarbon mineralization (CO_2 efflux) and solvent (DCM)extractable residuals. Brine salts inhibited biodegradation strongly at high levels and it was necessary to reduce the EC to less than 7 dS m^{-1} to avoid prolonged incubation periods. Rates of degradation were similar between moisture contents of 15 to 30% (w/w). The addition of nitrogen fertilizer was essential to initiate and maintain biodegradation. The

addition of 400 mg/kg of N was optimum and the form of N (nitrate, ammonium or slow release) did not affect degradation rates. Increasing the temperature from 32 to 37°C resulted in substantial rate increases as compared to ambient (22°C). These results of the laboratory studies served to establish targets for the operating parameters of the field unit.

TECHNOLOGY DEMONSTRATION SUMMARY

A field unit Bio-Reactor was constructed adjacent to a natural gas processing plant which provided essential services and waste heat so the unit could be operated year-round. The Bio-Reactor was comprised of a linear array of nine independent cells, each cell 9 m long, 3 m wide and 0.5 m deep. The contaminated soil was aggregated with a high speed custom designed rototiller and placed in the cells to a depth of either 15 or 30 cm. The waste material was treated in the Bio-Reactor for 11 months under the following conditions:

- Ambient temperature/Passive aeration
- Ambient temperature/Forced aeration
- Elevated temperature (35°C)/Passive aeration
- Elevated temperature(35°C)/Forced aeration
- 30 cm deep/35°C/Forced aeration

All loading depths other than the last treatment were 15 cm and all cells were leached and fertilized. The addition of hydrated lime caused the pH to increase to 11. CO_2 was forced through the waste, in order to reverse this effect, and the pH was reduced to 7.5 within hours.

Following the 11 month treatment in the Bio-Reactor, the contaminated soil from all treatments was combined and transferred to a heated and aerated Bio-Pile. The Bio-Pile is a secondary finishing unit (10 x 12 x 1 m deep) and a model for an operational unit.

TECHNOLOGY DEMONSTRATION RESULTS

The aggregation process resulted in the production of strong water stable aggregates and permitted the leaching of brine salts with a minimum of water, about 2 L/kg soil. The bulk density of the contaminated soil was very favourable being about 0.65 g/cm^3 and as a result forced aeration had no effect on hydrocarbon degradation, even with a 30 cm depth. Neither O_2 deficiency or CO_2 accumulation appeared to limit microbial activity, either in the Bio-Reactor or in the 1 m deep Bio-Pile.

During the 11 month residence time in the Bio-Reactor the hydrocarbon content in the heated cells decreased from 43,000 to 24,000 mg/kg (44% decrease) whereas in the unheated cells the decrease was 27%. Almost all of the losses could be attributed to microbial degradation as loss of volatiles was less than 1% of the total and losses in leachates were nil. Heating thus had favourable effects which were most pronounced during the winter but also during the growing season. Winter operation proved to be readily feasible with only light insulation of the waste surface. Once the material was mixed and transferred to the heated Bio-Pile, decreases in hydrocarbon content were small. In the June to November period, oil contents decreased from 25,000 to 22,000 mg/kg and after 1.5 years in the Bio-Pile the hydrocarbon content remains at 20,000 mg/kg and does not appear to be changing, i.e. the hydrocarbon contaminants are stable, probably due to sorption to clays and organic matter. Levels of N and P were not limiting and additions of fertilizer were unnecessary once readily degraded components had been utilized (about 1 month) and nutrient cycling mechanisms were functioning. The crude oil waste remains in the pile after 20 months (January 1995) without disturbance. Low level monitoring of oil content will continue to the end of the project to document long term changes.

A battery of ecotoxicity tests (germination, root elongation, earthworm survival, Microtox) were used to determine potential toxicity after 16 months of treatment. Although the residual hydrocarbons exceeded 20,000 mg/kg, no toxicity was detected in the treated topsoil, suggesting that well-weathered oil may pose minimal disposal or land application problems if salinity and wettability are not an issue.

STATUS

Treatment of the oil contaminated topsoil will continue in 1995. Two other hydrocarbon and salt contaminated wastes are under treatment by the Bio-Reactor/Bio-Pile technology. Additional ecotoxicity testing is currently underway to evaluate risk-based assessments of residual hydrocarbons. A final report on the project will be available in April 1996.

This Project Summary was prepared by R.M. Danielson, University of Calgary and is based on five reports published by the Canadian Association of Petroleum Producers [CAPP, (403) 267-1143] including the summary report *The Bio-Reactor Project: Executive Summary for 1992-93. The Remediation of Hydrocarbon and Brine Contaminated Topsoil (1994).*

This summary was prepared for:

The DESRT Program, Technology Development Directorate,
Environmental Protection Service, Environment Canada
Hull, Quebec

For further information, please contact:

Lin Callow, Gulf Canada Resources (403) 233-3924
Lisa Keller, Environment Canada (819) 953-0962
Walter Ceroici, Alberta Environment, (403) 427-6182

DISCLAIMER/REVIEW NOTICE

This document has been reviewed by the Technology Development Directorate of Environment Canada. The contents do not necessarily reflect the views and policies of agencies represented by DESRT. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

Environment Environnement Alberta

The National Contaminated Sites Remediation Program

DESRT Development and Demonstration of Site Remediation Technology

April 1993

- PROJECT SUMMARY -

BIOREMEDIATION PROJECT, PACIFIC PLACE SITE
WASTE STREAM TECHNOLOGY, INC.

INTRODUCTION

In 1989, the Canadian Council of Ministers of the Environment (CCME) acknowledged the need for a consistent national approach for the prioritization and remediation of high risk contaminated sites in Canada. In response to this need, CCME established the National Contaminated Sites Remediation Program (NCSRP), which is supported and administered through federal-provincial-territorial bilateral agreements.

The DESRT (Development and Demonstration of Site Remediation Technology) program is a component NCSRP. It was established to address the NCSRP objective of working with industry to stimulate the development and demonstration of new and innovative technologies with the potential to resolve problems that are critical to the environmental remediation of contaminated sites.

An innovative technology selected for participation in the DESRT program was a bioremediation process developed by Waste Stream Technology, Inc. A study of this technology was performed by Waste Stream Technology, Inc. and was jointly funded by Environment Canada, the British Columbia Ministry of Environment, Lands, and Parks, and the vendor.

SITE HISTORY

The Pacific Place site is an 82.5 hectare area of industrial land located along the north shore of False Creek in Vancouver, British Columbia. The site historically housed numerous industrial facilities including manufactured gas plants, rail yards, wood treatment facilities, metal works, and fuel storage and transfer facilities. As a result of these industrial activities, some areas of the Pacific Place site are contaminated with polycyclic aromatic hydrocarbons, chlorophenols, cyanide, heavy metals, and other organic and inorganic contaminants.

DESRT SUPPORTED WORK

The DESRT program supported a treatability study of several treatment technologies to evaluate their effectiveness for treating contaminated soils from the Pacific Place site. The technologies evaluated included thermal extraction, bioremediation, and stabilization/solidification, as well as the bioremediation process developed by Waste Stream Technology, Inc. The DESRT program has contributed approximately $1.13 million to the treatability studies carried out at the Pacific Place site.

TECHNOLOGY DESCRIPTION

Waste Stream's technology uses solid-phase, bioaugmented bioremediation for treating soils contaminated with organic compounds. In this solid-phase technology, soils are spread on an impervious treatment pad to a depth of about 45 cm. Frequent tilling of the soils introduces oxygen and promotes mixing of microorganisms and soil particles. Nutrients, moisture, and inoculum are applied by spraying or spreading and are tilled into the soil. Waste Stream maintains cultures of organisms, originally isolated from contaminated sites, that are known to degrade certain contaminants, and practices frequent inoculation of soils undergoing treatment with the most appropriate organism or combinations of organisms.

TECHNOLOGY DEMONSTRATION SUMMARY

Bench-scale treatability studies were performed using three different types of contaminated soils from the Pacific Place site. The studies were conducted over an 18- to 35-week period. Biostimulated, sterile control, and several bioaugmented soil pan reactors were established for each soil type. Before establishing the reactors, the soil samples were mixed and screened to remove material over 5 cm in diameter. All soil pans (except for the sterile controls) received daily moisture and nutrient amendments and bioaugmented reactors were inoculated with organisms at least weekly to maintain high microbial populations. Soils were monitored and sampled throughout the study for physical and chemical characteristics and microbial enumeration. Head space studies in flasks were also performed to evaluate any losses of organic contaminants due to volatilization.

Treatment goals for evaluating the reduction of organic contaminants were based on the British Columbia Standards for Managing Contamination from the Pacific Place Site.

DEMONSTRATION RESULTS

A summary of selected treatment results for biostimulated and two different bioaugmented studies, compared with initial soil concentrations and treatment goals, is provided in the table. The following are the key findings of the study:

- In general, concentrations of chlorophenols and PAHs were reduced rapidly over the first 2 weeks of the study and then in some reactors appeared to increase between 7 and 14 weeks into the study.

- Over the course of the study, reductions in total PAH concentrations in the bioactive soil pans with the highest contamination ranged from 28 to 35%. Reductions in the samples with lower concentrations of PAHs ranged from 15 to 78%.
- Chlorophenol concentrations were reduced by about 65% in the best performing soil pan.
- PAH reductions were enhanced using bioaugmentation, while the biostimulated reactors performed the best in reducing concentrations of chlorophenols.
- At the completion of the study, most of the PAH compounds in the sample with the highest initial concentrations, and all of the chlorophenol compounds significantly exceeded the treatment goals.
- Losses of organic compounds due to volatilization were not significant.

STATUS

The information provided in this summary is based on the vendor's report entitled *Treatability Study for Bioremediation of Contaminated Soils at the Pacific Place Site in Vancouver, British Columbia, Canada*; and a technical report prepared by Steams & Conrad Engineers to be published by Environment Canada, entitled *Technical Summary Report for the Pacific Place Project Special Waste Treatability Study Program*.

Project Summary prepared by Steams & Conrad Engineers for:
DESRT Program, Technology Development Branch
Conservation & Protection, Environment Canada
Hull, Quebec K1A 0H3

In cooperation with:
B.C. Ministry of the Environment, Parks & Lands

For Further Information Contact:
G. Hardy, Environment Canada (819) 953-0962
B. Ferguson, B.C. Environment (604) 356-6027

Table 1. Summary of Test Results

Contaminant	Sample 1 - M4 Organism T_o	T_f	Sample 2 - M5 Organism T_o	T_f	Sample 3 - Biostimulated T_o	T_f	Treatment Goal
Total PAHs	2053	683	177	53	156	133	200
Total Chlorophenols	NT	NT	NT	NT	53[1]	17[1]	10
TEH	9675	5630	NT	NT5	NT	NT	–

[1] Total Chlorophenols does not include tetrachlorophenol concentrations because they were not reported. Concentrations reported in mg/kg.
T_o Initial concentration
T_f Final concentration
NT Not tested
TEH Total Extractable Hydrocarbons

DISCLAIMER/REVIEW NOTICE
This document has been reviewed by the Technology Development Branch of Environment Canada. The contents do not necessarily reflect the views and policies of agencies represented by DESRT. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

The National Contaminated Sites Remediation Program

DESRT Development and Demonstration of Site Remediation Technology

April 1993

- PROJECT SUMMARY -

BIOREMEDIATION PROJECT, PACIFIC PLACE SITE
CHEM-SECURITY LTD., AND REMEDIATION TECHNOLOGIES, INC.

INTRODUCTION

In 1989, the Canadian Council of Ministers of the Environment (CCME) acknowledged the need for a consistent national approach for the prioritization and remediation of high risk contaminated sites in Canada. In response to this need, CCME established the National Contaminated Sites Remediation Program (NCSRP), which is supported and administered through federal-provincial-territorial bilateral agreements.

The DESRT (Development and Demonstration of Site Remediation Technology) program is a component of NCSRP. It was established to address the NCSRP objective of working with industry to stimulate the development and demonstration of new and innovative technologies with the potential to resolve problems that are critical to the environmental remediation of contaminated sites.

An innovative technology selected for participation in the DESRT program was a bioremediation process developed by Remediation Technologies, Inc. A study using the process was performed by Remediation Technologies, Inc. in association with Chem-Security Ltd., and was jointly funded by Environment Canada, the British Columbia Ministry of Environment, Lands, and Parks, and the vendors.

SITE HISTORY

The Pacific Place site is an 82.5 hectare area of industrial land located along the north shore of False Creek in Vancouver, British Columbia. The site historically housed numerous industrial facilities including manufactured gas plants, rail yards, wood treatment facilities, metal works, and fuel storage and transfer facilities. As a result of these industrial activities, some areas of the Pacific Place site are contaminated with polycyclic aromatic hydrocarbons, chlorophenols, cyanide, heavy metals, and other organic and inorganic contaminants.

DESRT SUPPORTED WORK

The DESRT program supported a treatability study of several treatment technologies to evaluate their effectiveness for treating contaminated soils from the Pacific Place site. The technologies evaluated included thermal extraction, bioremediation, and stabili-zation/solidification, and included the bioremediation process developed by Remediation Technologies, Inc. The DESRT program has contributed approximately $1.13 million to the treatability studies carried out at the Pacific Place site.

TECHNOLOGY DESCRIPTION

Two bioremediation technologies were tested in this study: aerobic slurry-phase and aerobic solid-phase treatment.

In the slurry-phase technology, soils are screened to remove oversize materials, mixed with water to form a slurry and placed into a reactor or series of reactors. The pH is adjusted and nutrients are added as needed to the reactor, which is continuously aerated and stirred. Usually, no inoculum is added to the slurry. Instead, indigenous microorganisms provided biodegradation when stimulated by optimum conditions. Upon completion of treatment, the slurry is filtered to remove moisture and the water is either re-used in the bioreactors, or treated and discharged.

In the solid-phase technology, soils are spread on an impervious treatment pad to a depth of about 30 cm. Frequent tilling of the soils introduces oxygen and promotes mixing of microorganisms and soil particles. Nutrients and moisture are applied by spraying or spreading and are tilled into the soil.

TECHNOLOGY DEMONSTRATION SUMMARY

Bench-scale treatability studies were performed using three different types of contaminated soils from the Pacific Place site. Before establishing bench-scale slurry and solid-phase reactors, the individual soil samples were homogenized and sieved.

The 12 week bench-scale slurry-phase testing was performed using 20-litre slurry reactors. Indigenous, nutrient amended and control reactors were established. Reactors were amended with nutrients and adjusted for pH at the beginning and at intervals throughout the study. The initial solids loading was 20%. Air was pumped into the slurry reactors for mixing and aeration.

The 16-week, bench-scale, solid-phase testing was conducted using polypropylene pans containing 2 to 3 kg of soil. A sterile control pan and an indigenous pan were established for each sample type. The soils were watered and tilled weekly. Nutrient amendments were made at the start of testing.

Soils and slurries were sampled at intervals during the treatment programs and tested for PAHs, chlorophenols, oil and grease, and metals. Treatment goals for evaluating the

reduction of organic contaminants were based on the British Columbia Standards for Managing Contamination from the Pacific Place Site.

A solid-phase mass balance study was also performed and involved three parts: a substrate removal study; a volatile emissions study; and a mineralization study using radio-labelled compounds (^{14}C-PCP or phenanthrene).

DEMONSTRATION RESULTS

A summary of treatment results compared to initial soil concentrations and treatment goals is provided in the table. The following are the key findings:

Slurry-Phase Studies

- The overall reduction in total PAH concentrations in all samples was less than 53%. Rapid reduction was seen in the first six weeks of the study, but later concentrations appeared to increase.
- Total chlorophenols were reduced by about 76% after 12 weeks of treatment.
- Oil and grease concentrations were reduced by between 87 and 93%.
- The treatment goals for the reduction of organic contaminants were not achieved.

Solid-Phase Studies

- Reduction in total PAHs ranged from zero to 59%, and in some cases increased concentrations were noted at the end of the treatment period.
- Reductions in total chlorophenols ranged from zero to 74%. Net similar reductions were observed in the abiotic soil pans.
- Volatilization of PAHs and chlorophenols was not significant. Abiotic losses other than volatilization appeared to account for most of the reductions in organic compounds.
- Solid-phase treatment did not achieve the treatability study goals.

STATUS

The information presented in this summary is based on the vendor's report entitled *Final Report for Treatability Testing of Ex Situ Bioremediation at the Pacific Place Site*, Remediation Technologies, Inc., June 1992; and a technical report prepared by Stearns & Conrad Engineers to be published under the DESRT program, entitled *Technical Summary Report For the Pacific Place Project Special Waste Treatability Study Program.*

Project Summary prepared by Stearns & Conrad Engineers for:
DESRT Program, Technology Development Branch
Conservation & Protection, Environment Canada
Hull, Quebec K1A 0H3

In cooperation with:
B.C. Ministry of the Environment, Lands & Parks

For further information contact:
G. Hardy, Environment Canada (819) 953-0962
B. Ferguson, B.C. Environment (604) 356-6027

Table 1 Summary of Test Results

Contaminant	Sample 1 T_i	Sample 1 T_f	Sample 2 T_i	Sample 2 T_f	Sample 3 T_i	Sample 3 T_f	Treatment Goal
Slurry Phase							
Total PAHs	895	421	78	4	246	NT	200
Total Chlorophenols	NT	NT	NT	NT	780	172	10
Oil and Grease	136,000	10,185	14,500	1,930	24,500	1,755	5000
Solid Phase							
Total PAHs	895	1453	86	73	246	NT	200
Total Chlorophenols	0.4	NT	0.1	NT	780	258	10
Oil and Grease	136,000	180,000	14,500	13,675	24,500	14,250	5000

Concentrations reported in mg/kg.
T_i Initial concentration
T_f Final concentration
NT Not tested

DISCLAIMER/REVIEW NOTICE
This document has been reviewed by the Technology Development Branch of Environment Canada. The contents do not necessarily reflect the views and policies of agencies represented by DESRT. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

The National Contaminated Sites Remediation Program

DESRT Development and Demonstration of Site Remediation Technology

April 1993

- PROJECT SUMMARY -

SLURRY-PHASE BIOREMEDIATION PROJECT, PACIFIC PLACE SITE
CHEMICAL WASTE MANAGEMENT OF CANADA, INC.

INTRODUCTION

In 1989, the Canadian Council of Ministers of the Environment (CCME) acknowledged the need for a consistent national approach for the prioritization and remediation of high risk contaminated sites in Canada. In response to this need, CCME established the National Contaminated Sites Remediation Program (NCSRP), which is supported and administered through federal-provincial-territorial bilateral agreements.

The DESRT (Development and Demonstration of Site Remediation Technology) program is a component of NCSRP. It was established to address the NCSRP objective of working with industry to stimulate the development and demonstration of new and innovative technologies with the potential to resolve problems that are critical to the environmental remediation of contaminated sites.

An innovative technology selected for participation in the DESRT program was a slurry-phase bioremediation process developed by Chemical Waste Management of Canada, Inc. A study using the process was performed by the vendor and was jointly funded by Environment Canada, the British Columbia Ministry of Environment, Lands, and Parks, and the Chemical Waste Management of Canada, Inc.

SITE HISTORY

The Pacific Place site is an 82.5 hectare area of industrial land located along the north shore of False Creek in Vancouver, British Columbia. The site historically housed numerous industrial facilities including manufactured gas plants, rail yards, wood treatment facilities, metal works, and fuel storage and transfer facilities. As a result of these industrial activities, some areas of the Pacific Place site are contaminated with polycyclic aromatic hydrocarbons, chlorophenols, cyanide, heavy metals, and other organic and inorganic contaminants.

DESRT SUPPORTED WORK

The DESRT program supported a treatability study of several treatment technologies to evaluate their effectiveness for treating contaminated soils from the Pacific Place site. The technologies evaluated included thermal extraction, bioremediation, and stabilization/solidification, and included the bioremediation process developed by Chemical Waste Management of Canada, Inc. The DESRT program has contributed approximately $1.13 million to the treatability studies carried out at the Pacific Place site.

TECHNOLOGY DESCRIPTION

Aerobic slurry-phase bioremediation was tested in this study. In slurry-phase technology, soils are screened to remove oversize materials, mixed with water to form a slurry, and placed into a reactor or series of reactors. The pH is adjusted and nutrients are added as needed to the reactor, which is continuously aerated and stirred to promote oxygenation and contact between the microorganisms and the soil particles. Inoculum may be added to the slurry, or indigenous microorganisms already present in the soil being treated may be depended upon to provide biodegradation when stimulated by optimum conditions. Upon completion of treatment, the slurry is filtered to remove moisture and the water is either re-used in the bioreactors, or treated and discharged.

TECHNOLOGY DEMONSTRATION SUMMARY

The treatability studies were performed using three different types of contaminated soils from the Pacific Place site. A 14-week bench-scale treatability study was performed using 75-L slurry bioreactors. Bioaugmented, biostimulated, and control reactors were established for each soil type. A volatilization (flask headspace) study was also performed to evaluate the effects of abiotic losses of contaminants due to volatilization.

Before setting up the bioreactors, the samples of each soil type were homogenized in a small cement mixer. Samples were analyzed for physical and chemical characteristics. Homogenized samples were then manually sieved through 3/8" sieves. The initial soil slurry concentration was 15% solids. The slurries were mixed by diffused oxygen and impeller blades. Nutrients were added to the reactors at the beginning of the study. The reactors were monitored and sampled frequently throughout the study. Slurry water and filter cakes were sampled and analyzed at the conclusion of the study to determine compliance with effluent standards and soil treatment goals.

Treatment goals for evaluating the reduction of organic contaminants were based on the British Columbia Standards for Managing Contamination from the Pacific Place Site.

DEMONSTRATION RESULTS

A summary of treatment results compared to initial soil concentrations and treatment goals of selected contaminants is provided in the table. The following are the key findings:

- Rapid reductions were reported in PAH concentrations in the first three weeks of the study, including those in the control reactors.
- Total PAHs were reduced by an average of 94.5% by the end of the study in the biologically active bioreactors in two of the soil types, and no reduction was seen in the third soil sample. The bioaugmented and biostimulated reactors generally indicated similar performance. Average reductions of 70% were noted in the sterile control reactors.
- Slightly greater reductions were reported in the low molecular weight (2 and 3 ring) PAHs than in the high molecular weight (4 and 5 ring) PAHs.
- The reductions in PAHs and total extractable hydrocarbons (TEH) observed in the control reactors and the results of the volatilization study indicate that most of the reduction of organic contaminants was the result of abiotic losses, other than volatilization.
- Initial concentrations of chlorophenols were much lower than expected.

STATUS

The information presented in this summary is based on the vendor's report entitled *Pacific Place Project Treatability Technical Study for British Columbia Hazardous Waste Management Corporation*, Chemical Waste Management of Canada, Inc.; and a technical report prepared by Stearns & Conrad Engineers to be published under the DESRT program, entitled *Technical Summary Report for the Pacific Place Project Special Waste Treatability Study Program*.

Project Summary prepared by Stearns & Conrad Engineers for:
DESRT Program, Technology Development Branch
Conservation & Protection, Environment Canada
Hull, Quebec K1A 0H3

In cooperation with:
British Columbia Ministry of the Environment, Lands & Parks

For further information contact:
G. Hardy, Environment Canada (819) 953-0962
B. Ferguson, B.C. Environment (604) 356-6027

Table 1 Summary of Test Results

Contaminant	Sample 1 T_o	Sample 1 T_f	Sample 2 T_o	Sample 2 T_f	Sample 3 T_o	Sample 3 T_f	Treatment Goal
Total PAHs	417	25	6	0.7	8	20	200
Total Chlorophenols	2	BDL	BDL	BDL	0.5	BDL	10
Oil and Grease	8300	3000	1100	1700	1300	1550	5000
TEH	470	157	8	BDL	16	9	–

Concentrations reported in mg/kg.
T_o Initial concentration
T_f Final concentration
TEH Total Extractable Hydrocarbons
BDL Below Detection Limits

DISCLAIMER/REVIEW NOTICE
This document has been reviewed by the Technology Development Branch of Environment Canada. The contents do not necessarily reflect the views and policies of agencies represented by DESRT. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

The National Contaminated Sites Remediation Program

DESRT Development and Demonstration of Site Remediation Technology

April 1993

- PROJECT SUMMARY -

STABILIZATION/SOLIDIFICATION PROJECT, PACIFIC PLACE SITE
NEWALTA CORPORATION

INTRODUCTION

In 1989, the Canadian Council of Ministers of the Environment (CCME) acknowledged the need for a consistent national approach for the prioritization and remediation of high risk contaminated sites in Canada. In response to this need, CCME established the National Contaminated Sites Remediation Program (NCSRP), which is supported and administered through federal-provincial-territorial bilateral agreements.

The DESRT (Development and Demonstration of Site Remediation Technology) program is a component of NCSRP. It was established to address the NCSRP objective of working with industry to stimulate the development and demonstration of new and innovative technologies with the potential to resolve problems that are critical to the environmental remediation of contaminated sites.

A technology selected for participation in the DESRT program was a stabilization/solidification process developed by Newalta Corporation. A study using the process was performed by Newalta Corporation and was jointly funded by Environment Canada, the British Columbia Ministry of Environment, Lands, and Parks, and the vendor.

SITE HISTORY

The Pacific Place site is an 82.5 hectare area of industrial land located along the north shore of False Creek in Vancouver, British Columbia. The site historically housed numerous industrial facilities including manufactured gas plants, rail yards, wood treatment facilities, metal works, and fuel storage and transfer facilities. As a result of these industrial activities, some areas of the Pacific Place site are contaminated with polycyclic aromatic hydrocarbons, chlorophenols, cyanide, heavy metals, and other organic and inorganic contaminants.

DESRT SUPPORTED WORK

The DESRT program supported a treatability study of several treatment technologies to evaluate their effectiveness for the treatment of contaminated soils from the Pacific Place site. The technologies evaluated included thermal extraction, bioremediation, and stabilization/solidification, as well as the stabilization/solidification process developed by Newalta. The DESRT program has contributed approximately $1.13 million to the treatability studies carried out at the Pacific Place site.

TECHNOLOGY DESCRIPTION

The stabilization technology used by Newalta is a physical encapsulation and a chemical fixation process based on the use of Portland cement and fly ash. The technology is used for immobilizing soils, ash, or sludges contaminated with leachable metals.

TECHNOLOGY DEMONSTRATION SUMMARY

Bench-scale treatability studies were performed using soil samples from the Pacific Place site. For the treatability study, Newalta stabilized two types of waste: a soil sample contaminated with high concentrations of metals and low concentrations of organics; and a tailings sample consisting of treated soil, baghouse ash, and cyclone solids from a thermal extraction process (the AOSTRA Taciuk Processor). Both samples were contaminated with significant concentrations of leachable lead.

The tailings samples were collected directly from the thermal processor and were not further homogenized or screened; the soil samples were homogenized before stabilization. Four stabilization formulations were initially prepared for each sample type. After ten days, the samples exhibiting a compressive strength of at least 2.5 tonne/ft^2 were subjected to leach testing to determine the optimal formulations. A 1:1 ratio of Portland cement and fly ash was used to stabilize the soil sample. A 1:4 ratio of Portland cement and fly ash was used for the tailings sample. The samples were mixed with the stabilization reagents, poured into molds, and cured for 56 days. Stabilized samples were then subjected to a set of tests as described below.

EVALUATION CRITERIA

One purpose of the stabilization/solidification study was to determine if treated material could be "delisted" as a hazardous (special) waste. In order to determine the potential for delisting, the B.C. "Draft Interim Protocol for Delisting Special Wastes and Residues" was used for evaluating the effectiveness of the treatment. This Protocol establishes numerical criteria for various use and disposal scenarios which are: unrestricted utilization; approved utilization (as determined by the Ministry); monofill disposal; and sanitary landfill disposal. The testing protocols included the following:

- Total Organic Carbon Content (TOC)
- Equilibrium Extraction (7-day leach)
- Sequential Chemical Extraction
- Dynamic Leach Test (ANS/ANSI 16.1)
- Hydraulic Conductivity
- Unconfined Compressive Strength
- Freeze/Thaw or Wet/Dry Testing
- Acid Neutralization Capacity

The two extraction test procedures apply to unrestricted utilization only, and are performed by first grinding the sample. The remaining tests (except TOC) are performed on monolithic (molded) samples and are used to evaluate the other three scenarios.

DEMONSTRATION RESULTS

Selected results of testing stabilized samples are summarized in the table. The following are the key findings of the study:

- Neither of the formulations tested in this treatability study achieved all of the standards necessary to allow the stabilized wastes to be delisted under any scenario, due primarily to the dynamic leach test results for both samples and the hydraulic conductivity of the stabilized tailings sample.

  However, the dynamic leach test leachability indices may have been calculated incorrectly, which could account for the poor results.

- It appears that both stabilized samples would achieve the standards to allow for disposal in a secure special waste landfill.

- A 33% increase in volume was reported for both the stabilized soil and the combined tailings.

STATUS

The information presented in this summary is based on the vendor's report entitled *Treatability Study Report, Pacific Place Soils Remediation Project*, June, 1992; and a technical report prepared by Stearns & Conrad Engineers to be published under the DESRT program, entitled *Technical Summary Report for the Pacific Place Project Special Waste Treatability Study Program.*

Project Summary prepared by Stearns & Conrad Engineers for:
DESRT Program, Technology Development Branch
Conservation & Protection, Environment Canada
Hull, Quebec K1A 0H3

In cooperation with:
British Columbia Ministry of Environment, Lands & Parks

For further information contact:
G. Hardy, Environment Canada (819) 953-0962
B. Ferguson, B.C. Environment (604) 356-6027

Table 1 Summary of Test Results

Test	Results		Delisting Standards		
	Stabilized Untreated Soil	Stabilized, Therm. Treat. Tailings	Approved Utilization	Sanitary Landfill	Monofill Landfill
Total Organic Carbon (%)	4.9	2.6	10	NS	NS
Hydraulic Conductivity (m/sec)	6.2×10^{-10}	1.2×10^{-7}	$<10^{-6}$	$<10^{-6}$	$<10^{-6}$
Unconfined Compressive Strength (kPa)	6070	3877	350	3500	350
Freeze/Thaw (% wt. loss)	0.3	0.6	<10	<10	<10
Acid Neutralization Capacity (eq/kg to pH 9)	>2.0	>1.6	>1	>1	>1
Dynamic Leach Test (leachability index)	>7 [1]	>7 [2]	>9	>8	>8

[1] Results for the following metals were reported: Ba, Cu, Sn, Zn.
[2] Results for the following metals were reported: Ba, Cr, Sn, Zn.
NS = No Standard
NT = Not Tested

DISCLAIMER/REVIEW NOTICE
This document has been reviewed by the Technology Development Branch of Environment Canada. The contents do not necessarily reflect the views and policies of agencies represented by DESRT. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

Environment Canada Environnement Canada

BC Environment CANADA'S GREEN PLAN

The National Contaminated Sites Remediation Program

DESRT Development and Demonstration of Site Remediation Technology

April 1993

- PROJECT SUMMARY -

STABILIZATION/SOLIDIFICATION PROJECT, PACIFIC PLACE SITE
BENNETT REMEDIATION SERVICES

INTRODUCTION

In 1989, the Canadian Council of Ministers of the Environment (CCME) acknowledged the need for a consistent national approach for the prioritization and remediation of high risk contaminated sites in Canada. In response to this need, CCME established the National Contaminated Sites Remediation Program (NCSRP), which is supported and administered through federal-provincial-territorial bilateral agreements.

The DESRT (Development and Demonstration of Site Remediation Technology) program is a component of NCSRP. It was established to address the NCSRP objective of working with industry to stimulate the development and demonstration of new and innovative technologies with the potential to resolve problems that are critical to the environmental remediation of contaminated sites.

An innovative technology selected for participation in the DESRT program was a stabilization/solidification process developed by Bennett Remediation Services. A study of the technology was performed by Bennett Remediation Services and was jointly funded by Environment Canada, the British Columbia Ministry of Environment, Lands, and Parks, and the vendor.

SITE HISTORY

The Pacific Place site is an 82.5 hectare area of industrial land located along the north shore of False Creek in Vancouver, British Columbia. The site historically housed numerous industrial facilities including manufactured gas plants, rail yards, wood treatment facilities, metal works, and fuel storage and transfer facilities. As a result of these industrial activities, some areas of the Pacific Place site are contaminated with polycyclic aromatic hydrocarbons, chlorophenols, cyanide, heavy metals, and other organic and inorganic contaminants.

DESRT SUPPORTED WORK

The DESRT program supported a treatability study of several treatment technologies to evaluate their effectiveness for treating contaminated soils from the Pacific Place site. The technologies evaluated included thermal extraction, bioremediation, and stabilization/solidification, and as well as the stabilization/solidification process developed by Bennett Remediation Services. The DESRT program has contributed approximately $1.13 million to the treatability studies carried out at the Pacific Place site.

TECHNOLOGY DESCRIPTION

The stabilization technology used by Bennett Remediation Services for this study was intended to immobilize inorganic contaminants. The technology involved the use of Portland cement. The addition of fly ash and an aluminosilicate were also evaluated.

TECHNOLOGY DEMONSTRATION SUMMARY

A bench-scale treatability study was performed using soil samples from the Pacific Place site that were contaminated with high concentrations of metals and low concentrations of organics.

For the treatability study, the vendor stabilized a soil sample that was first incinerated in the laboratory. Samples were first sieved with a #4 sieve, then heated in a laboratory oven at 371 °C until the weight loss was negligible. Several samples were processed to produce approximately 10 kg of sample for stabilization testing.

Six stabilization formulations were initially selected for testing. The formulations consisted of soil mixed with varying percentages of Type 1 Portland cement, fly ash, and/or an aluminosilicate. Following leaching and diffusion testing, two optimal formulations were selected for further evaluation: soil mixed with 10% cement (Formula 1); and soil mixed with 10% cement and 2% aluminosilicate (Formula 2). The samples were mixed and tamped into molds for curing. After curing, the samples were subjected to a set of tests as discussed below.

EVALUATION CRITERIA

One purpose of the stabilization/solidification study was to determine if treated material could be "delisted" as a hazardous (special) waste. In order to determine the potential for delisting, the B.C. "Draft Interim Protocol for Delisting Special Wastes and Residues" was used for evaluating the effectiveness of the treatment. This Protocol establishes numerical criteria for various use and disposal scenarios which are: unrestricted utilization; approved utilization (as determined by the Ministry); monofill disposal; and sanitary landfill disposal. The testing protocols included the following:

- Total Organic Carbon Content (TOC)
- Equilibrium Extraction (7-day leach)
- Sequential Chemical Extraction
- Dynamic Leach Test (ANS/ANSI 16.1)

- Hydraulic Conductivity
- Unconfined Compressive Strength
- Freeze/Thaw or Wet/Dry Testing
- Acid Neutralization Capacity

The two extraction test procedures apply to unrestricted utilization only, and are performed by first grinding the sample. The remaining tests (except TOC) are performed on monolithic (molded) samples and are used to evaluate the other three scenarios.

DEMONSTRATION RESULTS

Selected results of testing stabilized samples are summarized in the table. The following are the key findings:

- Both Formula 1 and Formula 2 failed to meet standards for delisting the stabilized ash under any of the utilization scenarios because of the high hydraulic conductivities reported.
- Formula 1 appeared to satisfy the standards for disposal in a secure, special waste landfill. No information was obtained for determining if Formula 2 met these standards.
- The vendor reported a slight decrease in volume (over the untreated soil) as a result of treatment.

STATUS

The information presented in this summary is based on the vendor's report entitled *Pacific Place Soils Remediation Project, Treatability Study Phase, Soil Stabilization Study, Volumes III and IV*, June 1992; and a technical report prepared by Stearns & Conrad Engineers to be published under the DESRT program, entitled *Technical Summary Report for the Pacific Place Project Special Waste Treatability Study Program.*

Project Summary prepared by Stearns & Conrad Engineers for:
DESRT Program, Technology Development Branch
Conservation & Protection, Environment Canada
Hull, Quebec K1A 0H3

In cooperation with:
British Columbia Ministry of Environment, Lands & Parks

For Further Information Contact:
G. Hardy, Environment Canada (819) 953-0962
B. Ferguson, B.C. Environment (604) 356-6027

Table 1 Summary of Test Results

Test	Results		Delisting Standards		
	Formula 1	Formula 2	Approved Utilization	Sanitary Landfill	Monofill Landfill
Total Organic Carbon (%)	0.7	0.7	10	NS	NS
Hydraulic Conductivity (m/sec)	3.0×10^{-7}	5.5×10^{-6}	$<10^{-4}$	$<10^{-4}$	$<10^{-4}$
Unconfined Compressive Strength (kPa)	4304	9309	350	3500	350
Freeze/Thaw (% wt. loss)	<1	<1	<10	<10	<10
Acid Neutralization Capacity (eq/kg to pH 9)	1.6	1.3	>1	>1	>1
Dynamic Leach Test (leachability index)	>9 [1]	>9 [2]	>9	>8	>8

[1] Results for the following metals were reported: Ba, Pb. ANSI/ANS 16.1 method not used by vendor.
[2] Results were reported for Ba only. ANSI/ANS 16.1 method not used by vendor.
NS = No Standard

DISCLAIMER/REVIEW NOTICE
This document has been reviewed by the Technology Development Branch of Environment Canada. The contents do not necessarily reflect the views and policies of agencies represented by DESRT. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

The National Contaminated Sites Remediation Program

DESRT Development and Demonstration of Site Remediation Technology

April 1993

- PROJECT SUMMARY -

STABILIZATION/SOLIDIFICATION PROJECT, PACIFIC PLACE SITE
WASTE STREAM TECHNOLOGY/WASTECH, INC.

INTRODUCTION

In 1989, the Canadian Council of Ministers of the Environment (CCME) acknowledged the need for a consistent national approach for the prioritization and remediation of high risk contaminated sites in Canada. In response to this need, CCME established the National Contaminated Sites Remediation Program (NCSRP), which is supported and administered through federal-provincial-territorial bilateral agreements.

The DESRT (Development and Demonstration of Site Remediation Technology) program is a component of NCSRP. It was established to address the NCSRP objective of working with industry to stimulate the development and demonstration of new and innovative technologies with the potential to resolve problems that are critical to the environmental remediation of contaminated sites.

An innovative technology selected for participation in the DESRT program was a stabilization/solidification process developed by Wastech, Inc. A study using that process was performed by Waste Stream Technology in association with Wastech, and was jointly funded by Environment Canada, the British Columbia Ministry of Environment, Lands, and Parks, and the vendors.

SITE HISTORY

The Pacific Place site is an 82.5 hectare area of industrial land located along the north shore of False Creek in Vancouver, British Columbia. The site historically housed numerous industrial facilities including manufactured gas plants, rail yards, wood treatment facilities, metal works, and fuel storage and transfer facilities. As a result of these industrial activities, some areas of the Pacific Place site are contaminated with polycyclic aromatic hydrocarbons, chlorophenols, cyanide, heavy metals, and other organic and inorganic contaminants.

DESRT SUPPORTED WORK

The DESRT program supported a treatability study of several treatment technologies to evaluate their effectiveness for treating contaminated soils from the Pacific Place site. The technologies evaluated included thermal extraction, bioremediation, and stabilization/solidification, as well as the stabilization/solidification process developed by Wastech. The DESRT program has contributed approximately $1.13 million to the treatability studies carried out at the Pacific Place site.

TECHNOLOGY DESCRIPTION

Wastech's stabilization technology uses proprietary bonding reagents (SuperSet®) to fix contaminants, and fly ash and Portland cement to provide a binder matrix. This process produces a dense, closed cell grout with calcium-silicate hydrogels. The process uses standard engineering and construction practices to prepare the material and mix it with the reagents. It can be applied to excavated soils or used for in-situ applications.

TECHNOLOGY DEMONSTRATION SUMMARY

The bench-scale treatability study was performed using soil samples contaminated with high concentrations of metals and low concentrations of organics from the Pacific Place site.

Before stabilizing the soil, it was screened and sieved to determine particle size distribution and chemical and physical analyses were performed on the sample.

About 18 different combinations of reagent/binder/sample mixes were generated for preliminary testing. From these, several formulations were selected for further evaluation. New samples were prepared and allowed to cure for two days. Samples that indicated a penetration resistance of greater than 4826 kPa were selected for leachate testing using the U.S. EPA Toxicity Characteristic Leaching Procedure (TCLP). These data, as well as implementability and cost, were used to optimize the final formulation which used a ratio of approximately 5 parts of soil, 1 part water mixed with SuperSet®, and 3 parts binder material.

EVALUATION CRITERIA

One purpose of the stabilization/solidification study was to determine if treated material could be "delisted" as a hazardous (special) waste. In order to determine the potential for delisting, the B.C. "Draft Interim Protocol for Delisting Special Wastes and Residues" was used for evaluating the effectiveness of the treatment. This Protocol establishes numerical criteria for various use and disposal scenarios which are: unrestricted utilization; approved utilization (as determined by the Ministry); monofill disposal; and sanitary landfill disposal. The testing protocols included the following:

- Total Organic Carbon Content (TOC)
- Equilibrium Extraction (7-day leach)
- Sequential Chemical Extraction
- Dynamic Leach Test (ANS/ANSI 16.1)
- Hydraulic Conductivity
- Unconfined Compressive Strength
- Freeze/Thaw or Wet/Dry Testing
- Acid Neutralization Capacity

The two extraction test procedures apply to unrestricted utilization only, and are performed by first grinding the sample. The remaining tests (except TOC) are performed on monolithic (molded) samples and are used to evaluate the other three scenarios.

DEMONSTRATION RESULTS

Selected results of testing stabilized samples are summarized in the table. The following are the key findings of the study:

- The treated sample appeared to satisfy the standards to allow delisting under the sanitary landfill and monofill utilization scenarios.
- The standards for the approved scenario were achieved except for the hydraulic conductivity results, which slightly exceeded the standard.
- Because alternative testing methods were used by the vendor and no replicate testing was performed, these data were not adequately verified in this study and additional testing would be required to confirm this conclusion.
- A 19% increase in the volume of the stabilized sample was reported.

STATUS

The information presented in this summary is based on the vendor's report entitled *Treatability Study for Stabilization/Fixation of Contaminated Soils at the Pacific Place Site in British Columbia, Canada*, revised July 27, 1992, and a technical report prepared by Stearns & Conrad Engineers to be published under the DESRT program, entitled *Technical Summary Report for the Pacific Place Project Special Waste Treatability Study Program.*

Project Summary prepared by Stearns & Conrad Engineers for:
DESRT Program, Technology Development Branch
Conservation & Protection, Environment Canada
Hull, Quebec K1A 0H3

In cooperation with:
British Columbia Ministry of the Environment, Lands & Parks

For further information contact:
G. Hardy, Environment Canada (819) 953-0962
B. Ferguson, B.C. Environment (604) 356-6027

Table 1 Summary of Test Results

Test	Result	Delisting Standards		
		Approved Utilization	Sanitary Landfill	Monofill Landfill
Total Organic Carbon (%)	NT	10	NS	NS
Hydraulic Conductivity (m/sec)	1.9×10^{-4}	$<10^{-4}$	$<10^{-4}$	$<10^{-4}$
Unconfined Compressive Strength (kPa)	6503	350	3500	350
Freeze/Thaw (% wt. loss)	4.0	<10	<10	<10
Acid Neutralization Capacity (eq/kg to pH 9)	1.6	>1	>1	>1
Dynamic Leach Test (leachability index)	>9 [1]	>9	>8	>8

[1] Results for the following metals were reported: As, Ba, Cr, Cu, Pb, Hg, Ni, Sn, Zn.
NS = No Standard
NT = Not tested

DISCLAIMER/REVIEW NOTICE
This document has been reviewed by the Technology Development Branch of Environment Canada. The contents do not necessarily reflect the views and policies of agencies represented by DESRT. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

The National Contaminated Sites Remediation Program

DESRT Development and Demonstration of Site Remediation Technology

April 1993

- PROJECT SUMMARY -

STABILIZATION/SOLIDIFICATION PROJECT, PACIFIC PLACE SITE
CHEMICAL WASTE MANAGEMENT OF CANADA, INC.

INTRODUCTION

In 1989, the Canadian Council of Ministers of the Environment (CCME) acknowledged the need for a consistent national approach for the prioritization and remediation of high risk contaminated sites in Canada. In response to this need, CCME established the National Contaminated Sites Remediation Program (NCSRP), which is supported and administered through federal-provincial-territorial bilateral agreements.

The DESRT (Development and Demonstration of Site Remediation Technology) program is a component of NCSRP. It was established to address the NCSRP objective of working with industry to stimulate the development and demonstration of new and innovative technologies with the potential to resolve problems that are critical to the environmental remediation of contaminated sites.

An innovative technology selected for participation in the DESRT program was a stabilization/solidification process developed by Chemical Waste Management of Canada, Inc. A study using the process was performed by the vendor and was jointly funded by Environment Canada, the British Columbia Ministry of Environment, Lands, and Parks, and Chemical Waste Management of Canada, Inc.

SITE HISTORY

The Pacific Place site is an 82.5 hectare area of industrial land located along the north shore of False Creek in Vancouver, British Columbia. The site historically housed numerous industrial facilities including manufactured gas plants, rail yards, wood treatment facilities, metal works, and fuel storage and transfer facilities. As a result of these industrial activities, some areas of the Pacific Place site are contaminated with polycyclic aromatic hydrocarbons, chlorophenols, cyanide, heavy metals, and other organic and inorganic contaminants.

DESRT SUPPORTED WORK

The DESRT program supported a treatability study of several treatment technologies to evaluate their effectiveness for treating contaminated soils from the Pacific Place site. The technologies evaluated included thermal extraction, bioremediation, and stabilization/solidification, as well as the stabilization/solidification process developed by Chemical Waste Management of Canada, Inc. The DESRT program has contributed approximately $1.13 million to the treatability studies carried out at the Pacific Place site.

TECHNOLOGY DESCRIPTION

Chemical Waste Management develops custom stabilization formulations on a waste-specific basis. In general, the technology uses Portland cement, pozzolans, and various combinations of these reagents. Minor additives are often used to promote setting and curing.

TECHNOLOGY DEMONSTRATION SUMMARY

Bench-scale treatability studies were performed using soil samples from the Pacific Place site that were contaminated with high concentrations of metals and low concentrations of organics.

Initially, numerous soil-stabilizing formulations were mixed in small batches, cured, then tested using a chemical extraction process to evaluate leaching from a ground sample of the stabilized material. Four variations of the formulation found to be successful in the initial screening process were then used to optimize the formulation and minimize reagent usage and reaction time. The optimal formulation was approximately 10 kg of soil mixed with water at a mix ratio of 0.1 and Portland cement at a mix ratio of 0.25. After mixing, the samples were placed in molds. Half of the samples were cured for 28 days, the other half for 56 days to compare the effect of curing time on performance. Cured samples were then subjected to a series of tests as discussed below.

EVALUATION CRITERIA

One purpose of the stabilization/solidification study was to determine if treated material could be "delisted" as a hazardous (special) waste. In order to determine the potential for delisting, the B.C. "Draft Interim Protocol for Delisting Special Wastes and Residues" was used for evaluating the effectiveness of the treatment. This Protocol establishes numerical criteria for various use and disposal scenarios which are: unrestricted utilization; approved utilization (as determined by the Ministry); monofill disposal; and sanitary landfill disposal. The testing protocols included the following:

- Total Organic Carbon Content (TOC)
- Equilibrium Extraction (7-day leach)
- Sequential Chemical Extraction
- Dynamic Leach Test (ANS/ANSI 16.1)
- Hydraulic Conductivity
- Unconfined Compressive Strength
- Freeze/Thaw or Wet/Dry Testing
- Acid Neutralization Capacity

The two extraction test procedures apply to unrestricted utilization only, and are performed by first grinding the sample. The remaining tests (except TOC) are performed on monolithic (molded) samples and are used to evaluate the other three scenarios.

DEMONSTRATION RESULTS

Selected results of testing solidified samples are summarized in the table. The following are the key findings of the study:

- The formulation cured for 56 days met the standards for delisting under the approved and monofill utilization scenarios. The option for sanitary landfill disposal was not completely evaluated because the vendor's equipment did not allow measurement of sufficiently high compressive strength.
- The samples cured for 28 days failed the freeze/thaw test for all scenarios.
- Both formulations appeared to satisfy standards for disposal in a secure special waste landfill.
- An average increase in the volume of the stabilized sample was approximately 11%.

STATUS

The information presented in this summary is based on the vendor's report entitled *Pacific Place Project Treatability Technical Study for British Columbia Hazardous Waste Management Corporation*, June 1992; and a technical report prepared by Stearns & Conrad Engineers to be published under the DESRT program, entitled *Technical Summary Report for the Pacific Place Project Special Waste Treatability Study Program*.

Project Summary prepared by Stearns & Conrad Engineers for:
DESRT Program, Technology Development Branch
Conservation & Protection, Environment Canada
Hull, Quebec K1A 0H3

In cooperation with:
British Columbia Ministry of Environment, Lands & Parks

For further information contact:
G. Hardy, Environment Canada (819) 953-0962
B. Ferguson, B.C. Environment (604) 356-6027

Table 1. Summary of Test Results

	Results		Delisting Standards		
	28 day Cure	56 day Cure	Approved Utilization	Sanitary Landfill	Monofill Landfill
Total Organic Carbon (%)	1.6	4.3	10	NS	NS
Hydraulic Conductivity (m/sec)	3×10^{-6}	5×10^{-6}	$<10^{-6}$	$<10^{-6}$	$<10^{-6}$
Unconfined Compressive Strength (kPa)	2650	>2650	350	3500	350
Freeze/Thaw (% wt. loss)	30.7	2.3	<10	<10	<10
Wet/Dry (% wt. loss)	<0	<0			
Acid Neutralization Capacity (eq/kg to pH 9)	>4.5	>4	>1	>1	>1
Dynamic Leach Test (leachability index)	>9 [1]	>9 [1]	>9	>8	>8

[1] Results for the following metals were reported: As,Ba, Cd, Cr, Cu, Pb, Ni, Zn.
NS = No Standard
NT = Not Tested

DISCLAIMER/REVIEW NOTICE
This document has been reviewed by the Technology Development Branch of Environment Canada. The contents do not necessarily reflect the views and policies of agencies represented by DESRT. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

The National Contaminated Sites Remediation Program

DESRT Development and Demonstration of Site Remediation Technology

April 1993

- PROJECT SUMMARY -

STABILIZATION/SOLIDIFICATION PROJECT, PACIFIC PLACE SITE
OGDEN ENVIRONMENTAL SERVICES/CHEMFIX TECHNOLOGIES, INC.
BRITISH COLUMBIA

INTRODUCTION

In 1989, the Canadian Council of Ministers of the Environment (CCME) acknowledged the need for a consistent national approach for the prioritization and remediation of high risk contaminated sites in Canada. In response to this need, CCME established the National Contaminated Sites Remediation Program (NCSRP), which is supported and administered through federal-provincial-territorial bilateral agreements.

The DESRT (Development and Demonstration of Site Remediation Technology) program is a component of NCSRP. It was established to address the NCSRP objective of working with industry to stimulate the development and demonstration of new and innovative technologies with the potential to resolve problems that are critical to the environmental remediation of contaminated sites.

An innovative technology selected for participation in the DESRT program was a stabilization/solidification process developed by Chemfix Technologies, Inc. A study using the process was performed by Ogden Environmental Services in association with Chemfix, and was jointly funded by Environment Canada, the British Columbia Ministry of Environment, Lands, and Parks, and the vendors.

SITE HISTORY

The Pacific Place site is an 82.5 hectare area of industrial land located along the north shore of False Creek in Vancouver, British Columbia. The site historically housed numerous industrial facilities including manufactured gas plants, rail yards, wood treatment facilities, metal works, and fuel storage and transfer facilities. As a result of these industrial activities, some areas of the Pacific Place site are contaminated with polycyclic aromatic hydrocarbons, chlorophenols, cyanide, heavy metals, and other organic and inorganic contaminants.

DESRT SUPPORTED WORK

The DESRT program supported a treatability study of several treatment technologies to evaluate their effectiveness for treating contaminated soils from the Pacific Place site. The technologies evaluated included thermal extraction, bioremediation, and stabilization/solidification, as well as the stabilization/solidification process developed by Chemfix. The DESRT program has contributed approximately $1.13 million to the treatability studies carried out at the Pacific Place site.

TECHNOLOGY DESCRIPTION

The Chemfix technology is designed to stabilize and solidify metals and selected organic contaminants in soils, liquids, and sludge. The technology uses proprietary calcium and poly-silicate-based reagents (CHEMSET), organic bonding reagents, and precipitating agents. Water is added as necessary and reagent combinations and proportions are optimized for each waste stream. The Chemfix treatment system is a mobile unit consisting of a feed system, homogenizer (for mixing reagents), and pug mill.

TECHNOLOGY DEMONSTRATION SUMMARY

A bench-scale treatability study was performed using soil samples contaminated with high concentrations of metals and low concentrations of organics from the Pacific Place site.

For the treatability study, the vendor stabilized a soil sample that was first incinerated in the laboratory in a spouting bed combustor. Following the incineration, laboratory analyses indicated that lead exceeded allowable leachate standards, therefore requiring stabilization. Before processing, the soil was screened to pass through a 1/8 inch diameter screen and blended. The laboratory-incinerated soils were provided to Chemfix for the stabilization process. The samples were stabilized using a soluble silicate process, and were tested by Ogden at a contracted laboratory.

Initially, three stabilization formulations were selected for evaluation using the U.S. EPA Toxicity Characteristic Leaching Procedure (TCLP). A final formulation was selected for further evaluation based on coast effectiveness. The incinerated soils were mixed with the stabilizing reagents, placed into molds and allowed to cure for 14 days before further testing.

EVALUATION CRITERIA

One purpose of the stabilization/solidification study was to determine if treated material could be "delisted" as a hazardous (special) waste. In order to determine the potential for delisting, the B.C. "Draft Interim Protocol for Delisting Special Wastes and Residues" was used for evaluating the effectiveness of the treatment. This Protocol establishes numerical criteria for various use and disposal scenarios which are: unrestricted utilization; approved utilization (as determined by the Ministry); monofill disposal; and sanitary landfill disposal. The testing protocols included the following:

- Total Organic Carbon Content (TOC)
- Equilibrium Extraction (7-day leach)
- Sequential Chemical Extraction
- Dynamic Leach Test (ANS/ANSI 16.1)
- Hydraulic Conductivity
- Unconfined Compressive Strength
- Freeze/Thaw or Wet/Dry Testing
- Acid Neutralization Capacity

The two extraction test procedures apply to unrestricted utilization only, and are performed by first grinding the sample. The remaining tests (except TOC) are performed on monolithic (molded) samples and are used to evaluate the other three scenarios.

DEMONSTRATION RESULTS

Selected results of testing stabilized samples are summarized in the table. The following are the key findings:

- The stabilization formulation used in this study failed to meet standards for delisting the stabilized material under the unrestricted and "approved" utilization scenario.
- The formulation used appeared to satisfy the standards for delisting the material under the sanitary and monofill landfill scenarios. However, due to limited analytical testing, this is a tentative conclusion and further confirmatory testing would be required.

STATUS

The information presented in this summary is based on the vendor's report entitled *Pacific Place Treatability Study*, June, 1992; and a technical report prepared by Stearns & Conrad Engineers to be published under the DESRT program, entitled *Technical Summary Report for the Pacific Place Project Special Waste Treatability Study Program*.

Project Summary prepared by Stearns & Conrad Engineers for:
DESRT Program, Technology Development Branch
Conservation & Protection, Environment Canada
Hull, Quebec K1A 0H3

In cooperation with:
British Columbia Ministry of Environment, Lands & Parks

For Further Information Contact:
L. Keller, Environment Canada (819) 953-0962
B. Ferguson, B.C. Environment (604) 356-6027

Table 1. Summary of Test Results

		Delisting Standards		
		Approved Utilization	Sanitary Landfill	Monofill Landfill
Total Organic Carbon (%)	NT	10	NS	NS
Hydraulic Conductivity (m/sec)	4×10^{-8}	$<10^{-9}$	$<10^{-8}$	$<10^{-8}$
Unconfined Compressive Strength (kPa)	3987	350	3500	350
Freeze/Thaw (% wt. loss)	1.9	<10	<10	<10
Acid Neutralization Capacity (eq/kg to pH 8)	5000	>1	>1	>1
Dynamic Leach Test (leachability index)	NC [1]	>8	>8	>8

[1] Leachability indices were not calculated; incorrect method used.
NC = Not calculated
NS = No Standard
NT = Not Tested

DISCLAIMER/REVIEW NOTICE
This document has been reviewed by the Technology Development Branch of Environment Canada. The contents do not necessarily reflect the views and policies of agencies represented by DESRT. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

The National Contaminated Sites Remediation Program

DESRT Development and Demonstration of Site Remediation Technology

April 1993

- PROJECT SUMMARY -

STABILIZATION/SOLIDIFICATION PROJECT, PACIFIC PLACE SITE
BOVAR ENVIRONMENTAL SERVICES/CHEM-SECURITY LTD.

INTRODUCTION

In 1989, the Canadian Council of Ministers of the Environment (CCME) acknowledged the need for a consistent national approach for the prioritization and remediation of high risk contaminated sites in Canada. In response to this need, CCME established the National Contaminated Sites Remediation Program (NCSRP), which is supported and administered through federal-provincial-territorial bilateral agreements.

The DESRT (Development and Demonstration of Site Remediation Technology) program is a component of NCSRP. It was established to address the NCSRP objective of working with industry to stimulate the development and demonstration of new and innovative technologies with the potential to resolve problems that are critical to the environmental remediation of contaminated sites.

An innovative technology selected for participation in the DESRT program was a stabilization/solidification process developed by Bovar Environmental Services. A study using the technology was performed by Chem-Security Ltd. in association with Bovar, and was jointly funded by Environment Canada, the British Columbia Ministry of Environment, Lands, and Parks, and the vendors.

SITE HISTORY

The Pacific Place site is an 82.5 hectare area of industrial land located along the north shore of False Creek in Vancouver, British Columbia. The site historically housed numerous industrial facilities including manufactured gas plants, rail yards, wood treatment facilities, metal works, and fuel storage and transfer facilities. As a result of these industrial activities, some areas of the Pacific Place site are contaminated with polycyclic aromatic hydrocarbons, chlorophenols, cyanide, heavy metals, and other organic and inorganic contaminants.

DESRT SUPPORTED WORK

The DESRT program supported a treatability study of several treatment technologies to evaluate their effectiveness for treating contaminated soils from the Pacific Place site. The technologies evaluated included thermal extraction, bioremediation, and stabilization/solidification, as well as the stabilization/solidification process developed by Bovar. The DESRT program has contributed approximately $1.13 million to the treatability studies carried out at the Pacific Place site.

TECHNOLOGY DESCRIPTION

The Chem-Security/Bovar technology uses various reagents for stabilizing inorganic contaminants, depending on the characteristics of the waste. In general, Portland cement and proprietary metal stabilizers (sodium silicates) form the basis of the technology. Wastes to be stabilized are mixed with reagents and allowed to cure before disposal.

TECHNOLOGY DEMONSTRATION SUMMARY

Bench-scale treatability studies were performed using soil samples from the Pacific Place site that were contaminated with high concentrations of metals and low concentrations of organics.

In the study, the soil was screened through 100- and 20-mm mesh sieves, dried, and homogenized before adding the stabilization reagents. Following an initial screening process using six different formulations, the optimum weights of soil, cement, and admixtures (an approximate ratio of one part Portland cement and stabilizers and two parts soil) were combined with sufficient water to make a cement slurry. The material was then mixed in a blender, placed in molds, tamped, and allowed to cure for 26 days. Cured samples were subjected to a series of tests as described below.

EVALUATION CRITERIA

One purpose of the stabilization/solidification study was to determine if treated material could be "delisted" as a hazardous (special) waste. In order to determine the potential for delisting, the B.C. "Draft Interim Protocol for Delisting Special Wastes and Residues" was used for evaluating the effectiveness of the treatment. This Protocol establishes numerical criteria for various use and disposal scenarios which are: unrestricted utilization; approved utilization (as determined by the Ministry); monofill disposal; and sanitary landfill disposal. The testing protocols included the following:

- Total Organic Carbon Content (TOC)
- Equilibrium Extraction (7-day leach)
- Sequential Chemical Extraction
- Dynamic Leach Test (ANS/ANSI 16.1)
- Hydraulic Conductivity
- Unconfined Compressive Strength
- Freeze/Thaw or Wet/Dry Testing
- Acid Neutralization Capacity

The two extraction test procedures apply to unrestricted utilization only, and are performed by first grinding the sample. The remaining tests (except TOC) are performed on monolithic (molded) samples and are used to evaluate the other three scenarios.

DEMONSTRATION RESULTS

Selected results of the stabilization/solidification study are reported in the table below. The following are the key findings:

- The formulation used for this testing program did not meet standards for delisting under any of the utilization scenarios.
- The formulation would have achieved standards for delisting under an "approved" utilization scenario, except for the poor freeze/thaw test results. It is possible that the poor results were due to the use of a more aggressive test procedure than required.
- Treated material appears to meet performance standards for disposal in a secure chemical waste landfill.
- A 50% increase was reported in the volume of the sample following stabilization was reported.

STATUS

The information presented in this summary is based on the vendor's report entitled *Final Report for the Treatability Testing of Stabilization of Pacific Place Soils*, June, 1992; and a technical report prepared by Stearns & Conrad Engineers to be published under the DESRT program, entitled *Technical Summary Report for the Pacific Place Project Special Waste Treatability Study Program.*

Project Summary prepared by Stearns & Conrad Engineers for:
DESRT Program, Technology Development Branch
Conservation & Protection, Environment Canada
Hull, Quebec K1A 0H3

In cooperation with:
British Columbia Ministry of the Environment, Lands & Parks

For Further Information Contact:
G. Hardy, Environment Canada (819) 953-0962
B. Ferguson, B.C. Environment (604) 356-6027

Table 1. Summary of Test Results

Test	Result	Delisting Standards		
		Approved Utilization	Sanitary Landfill	Monofill Landfill
Total Organic Carbon (%)	<0.1	10	NS	NS
Hydraulic Conductivity (m/sec)	5.0×10^{-7}	$<10^{-6}$	$<10^{-6}$	$<10^{-6}$
Unconfined Compressive Strength (kPa)	9680	350	3500	350
Freeze/Thaw (% wt. loss) [1]	17.2	<10	<10	<10
Wet/Dry (% wt. loss) [1]	11.6			
Acid Neutralization Capacity (eq/kg to pH 9)	6	>1	>1	>1
Dynamic Leach Test (leachability index)	>9 [2]	>9	>8	>8

[1] Performed alternate methods.
[2] Results for the following metals were reported: Ba, Cr, Zn.
NS = No Standard

DISCLAIMER/REVIEW NOTICE
This document has been reviewed by the Technology Development Branch of Environment Canada. The contents do not necessarily reflect the views and policies of agencies represented by DESRT. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

The National Contaminated Sites Remediation Program

DESRT Development and Demonstration of Site Remediation Technology

April 1993

- PROJECT SUMMARY -

THERMAL EXTRACTION PROJECT, PACIFIC PLACE SITE
CHEMICAL WASTE MANAGEMENT OF CANADA, INC.

INTRODUCTION

In 1989, the Canadian Council of Ministers of the Environment (CCME) acknowledged the need for a consistent national approach for the prioritization and remediation of high risk contaminated sites in Canada. In response to this need, CCME established the National Contaminated Sites Remediation Program (NCSRP), which is supported and administered through federal-provincial-territorial bilateral agreements.

The DESRT (Development and Demonstration of Site Remediation Technology) program is a component of NCSRP. It was established to address the NCSRP objective of working with industry to stimulate the development and demonstration of new and innovative technologies having the potential to resolve problems that are critical to the environmental remediation of contaminated sites.

An innovative technology selected for participation in the DESRT program was a thermal extraction process developed by Chemical Waste Management of Canada, Inc. A project using that technology was jointly funded by Environment Canada, the British Columbia Ministry of Environment, Lands, and Parks, and the vendor.

SITE HISTORY

The Pacific Place site is an 82.5 hectare area of industrial land located along the north shore of False Creek in Vancouver, British Columbia. The site historically housed numerous industrial facilities including manufactured gas plants, rail yards, wood treatment facilities, metal works, and fuel storage and transfer facilities. As a result of these industrial activities, some areas of the Pacific Place site are contaminated with polycyclic aromatic hydrocarbons, chlorophenols, cyanide, heavy metals, and other organic and inorganic contaminants.

DESRT SUPPORTED WORK

The DESRT program supported a treatability study of several treatment technologies to evaluate their effectiveness for treating contaminated soils from the Pacific Place site. The technologies evaluated included thermal extraction, bioremediation, and stabilization/ solidification, as well as the thermal extraction process developed by Chemical Waste Management, Inc. The DESRT program has contributed approximately $1.13 million to the treatability studies carried out at the Pacific Place site.

TECHNOLOGY DESCRIPTION

The X*TRAX system, developed by Chemical Waste Management, Inc., is a low temperature thermal separation process that vaporizes or steam strips organic compounds from soils or sludges. It consists of an externally fired rotary dryer and gas treatment system. Operating temperatures average about 430°C. A simplified flow diagram of the X*TRAX system is provided in the accompanying figure.

Nitrogen is used as a carrier gas for the volatilized organics which are transported from the rotary dryer to a gas treatment system. The gas treatment system includes a spray tower/scrubber, shell-and-tube heat exchangers for condensing the gases, and two activated carbon filters for treating residual organics in the gas stream. In the pilot- and full-scale units, most of the nitrogen gas is recycled back into the system.

Liquids and particulates (and less volatile organic compounds) from the spray tower are passed through a gravity phase separator and are then filtered to separate out solids. Condensed liquids from the heat exchangers are composited, filtered, and phase separated for further treatment as necessary.

The full-scale X*TRAX system is a transportable unit capable of treating up to 125 tonnes per day of soil with a moisture content of 20%. The vendor also operates a pilot-scale unit that is mobile and can treat about 5 tonnes per day of material containing 30% moisture.

TECHNOLOGY DEMONSTRATION SUMMARY

Bench-scale treatability studies were performed using three different types of contaminated soils from the Pacific Place site. Treatability testing was conducted using a laboratory-scale X*TRAX unit. Treatment goals for evaluating the reduction of organic contaminants were based on the British Columbia Standards for Managing Contamination from the Pacific Place Site.

Two operating temperatures were tested in these studies: 482°C and 371°C. Before processing, the samples were screened through a 1/4-inch sieve and then homogenized. Feed samples were collected once each hour and were composited for each temperature condition. Treated solids and condensates were collected every 15 minutes. The condensates and phase separator liquid were filtered through 25-micron filter paper.

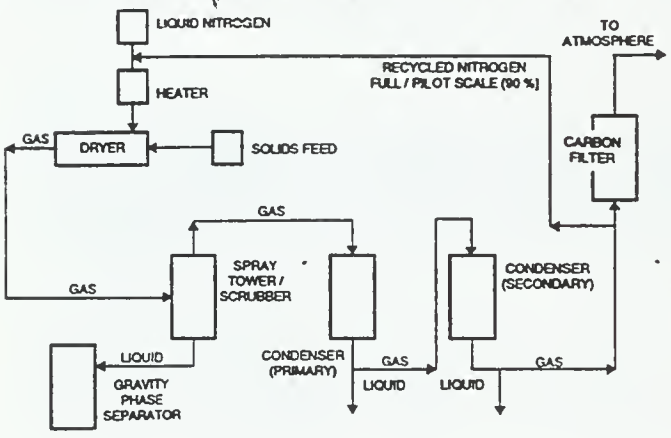
The feed and all treatment by-products were subjected to chemical and physical analyses to evaluate performance and perform a mass balance. Analysis of emissions during the treatability study was not performed due to the small scale of the equipment.

DEMONSTRATION RESULTS

A summary of treatment results for the higher operating temperature (482°C) compared with initial soil concentrations and treatment goals is provided in the table. The following are the key findings of the study:

- In the sample with the highest concentrations of total PAHs, these compounds were reduced by 99.93% and 99.39% in the 482°C and 371°C operating conditions, respectively. The concentrations of individual and total PAHs in the treated soil were well below the treatment goals.
- Pentachlorophenol was reduced by an average of approximately 98%, and 2,3,4,6-tetrachlorophenol by an average of approximately 92%.
- The concentrations of chlorophenols were all below the treatment goals except for one sample with a high detection limit.
- Neither total metals concentrations, nor metals leachability characteristics changed significantly as a result of the treatment process.
- A significant proportion of the organic contaminants were removed in the spray tower/scrubber and were detected in the filtrate.

Figure 1. Schematic Diagram of X*TRAX Process



STATUS

The information presented in this summary is based on the vendor's report entitled *Pacific Place Project Treatment Technical Study for British Columbia Hazardous Waste Management Corporation*, June 1992; and a technical report prepared by Stearns & Conrad Engineers, to be published under the DESRT program, entitled *Technical Summary Report for the Pacific Place Project Special Waste Treatability Study Program.*

Project Summary prepared by Stearns & Conrad Engineers for:
DESRT Program, Technology Development Branch
Conservation & Protection, Environment Canada
Hull, Quebec K1A 0H3

In cooperation with:
B.C. Ministry of the Environment, Land and Parks

For further information contact:
G. Hardy, Environment Canada (819) 953-0962
B. Ferguson, B.C. Environment (604) 356-6027

Table 1. Summary of Test Results

Contaminant	Sample 1 Feed	Sample 1 Treated	Sample 2 Feed	Sample 2 Treated	Sample 3 Feed	Sample 3 Treated	Treatment Goal
Total PAHs	3428	2	54	BDL	193	0.2	20
Total Chlorophenols	BDL	BDL	14	0.6	BDL	BDL	1
Oil and Grease	3200	88	520	60	1400	88	1000
TEH	7900	<25	29	<25	610	<25	–

Note: Results are from 482°C operating temperature
All concentrations are in mg/kg
BDL = Below Detection Limits
ND = Not Detected
TEH = Total extractable hydrocarbons

DISCLAIMER/REVIEW NOTICE
This document has been reviewed by the Technology Development Branch of Environment Canada. The contents do not necessarily reflect the views and policies of agencies represented by DESRT. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

The National Contaminated Sites Remediation Program

DESRT Development and Demonstration of Site Remediation Technology

April 1993

- PROJECT SUMMARY -

THERMAL EXTRACTION PROJECT, PACIFIC PLACE SITE
NEWALTA CORPORATION/UMATAC INDUSTRIAL PROCESSES

INTRODUCTION

In 1989, the Canadian Council of Ministers of the Environment (CCME) acknowledged the need for a consistent national approach for the prioritization and remediation of high risk contaminated sites in Canada. In response to this need, CCME established the National Contaminated Sites Remediation Program (NCSRP), which is supported and administered through federal-provincial-territorial bilateral agreements.

The DESRT (Development and Demonstration of Site Remediation Technology) program is a component of NCSRP. It was established to address the NCSRP objective of working with industry to stimulate the development and demonstration of new and innovative technologies with the potential to resolve problems that are critical to the environmental remediation of contaminated sites.

An innovative technology selected for participation in the DESRT program was a thermal extraction process developed by UMATAC Industrial Processes. A project of that technology was performed by Newalta Corporation in association with UMATAC, and was jointly funded by Environment Canada, the British Columbia Ministry of Environment, Lands, and Parks, and the vendors.

SITE HISTORY

The Pacific Place site is an 82.5 hectare area of industrial land located along the north shore of False Creek in Vancouver, British Columbia. The site historically housed numerous industrial facilities including manufactured gas plants, rail yards, wood treatment facilities, metal works, and fuel storage and transfer facilities. As a result of these industrial activities, some areas of the Pacific Place site are contaminated with polycyclic aromatic hydrocarbons, chlorophenols, cyanide, heavy metals, and other organic and inorganic contaminants.

DESRT SUPPORTED WORK

The DESRT program supported a treatability study of several treatment technologies to evaluate their effectiveness for treating contaminated soils from the Pacific Place site. The technologies evaluated included thermal extraction, bioremediation, and stabilization/ solidification, as well as the thermal extraction process developed by UMATAC. The DESRT program has contributed approximately $1.13 million to the treatability studies carried out at the Pacific Place site.

TECHNOLOGY DESCRIPTION

The AOSTRA Taciuk Processor (ATP) is a thermal extraction technology developed by UMATAC Industrial Processes that separates organics from solids by pyrolysis and distillation. A flow diagram of the ATP is provided in the accompanying figure. The processor consists of a rotary kiln with a preheat zone, operating at about 260°C; a reaction zone, operating at between 317 and 649°C; and a combustion zone, operating at 538 to 815°C. Water vapour and the more volatile organics are extracted in the preheat zone. Oils and heavier organics are removed in the reaction zone. Both the preheat and the reaction zones are maintained in anaerobic conditions to minimize oxidation of the organics. The combustion zone burns coke from thermal cracking that forms on the solids in the reaction zone..

The flue gas from the combustion zone is passed through a baghouse and a wet scrubber. Treated solids are discharged from the kiln as tailings. The steam and organics produced in the preheat reaction zones are withdrawn and condensed in separate vapour trains. The wastewater produced generally requires treatment before disposal. The oily waste must either be incinerated in a hazardous waste incinerator or recycled and burned as fuel.

TECHNOLOGY DEMONSTRATION SUMMARY

Bench- and pilot-scale treatability studies were performed using four different types of contaminated soils from the Pacific Place site. In addition, a bench-scale wastewater treatment study was performed to evaluate the effectiveness of a combination of standard treatment technologies. This project summary discusses only the pilot-scale study. Treatment goals for evaluating the reduction of organic contaminants were based on the British Columbia Standards for Managing Contamination from the Pacific Place Site.

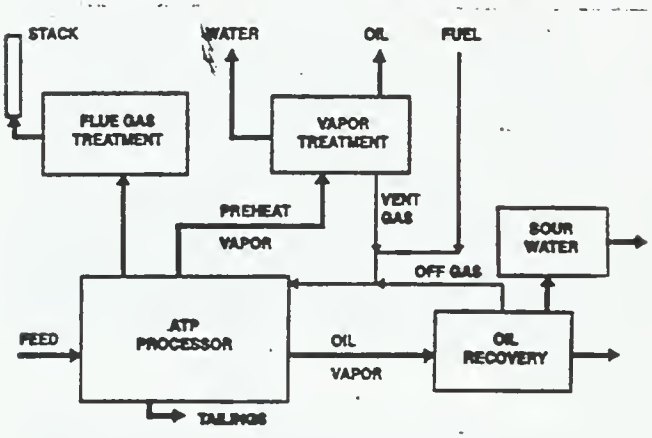
Four separate tests averaging about four hours in length were performed using UMATAC's 5-tonne-per-hour prototype unit. Feed rates ranged from 2.7 to 4.1 tonnes per hour. During each test run, samples of the feed and samples of the treated tailings (treated soils, baghouse ash, and cyclone ash) were collected every 30 minutes. Composite samples of each of these were submitted for analytical testing. Condensate samples of both water and oil were also collected from each run every 30 minutes and analyzed. Stack emissions was also monitored during three test runs to test stack emissions and to calculate destruction and removal efficiencies (DRE) and mass balances.

DEMONSTRATION RESULTS

Analytical results for the treated soils in comparison with the feed soils, as well as treatment goals are provided in the table. Key findings of the study include:

- The ATP achieved nearly 100% removal of organic contaminants from the soil and demonstrated that treated soils met the treatment goals for organic contaminants. However, concentrations of organics in the feed were low due to dilution from the addition of sand before processing.
- Destruction and removal efficiences for PAHs ranging from 98.41 to 100.00% were calculated by the vendor.
- Dibenzo-dioxin and dibenzofuran concentrations were reduced in the soil as a result of treatment, but were present at significant concentrations in the condensed oil from two of the test runs.
- In general, the concentrations of metals were reduced in the treated soils from what was reported in the feed, and were higher in the cyclone dust and baghouse ash (particularly arsenic, copper, lead, tin, and zinc).
- Stack emissions standards for metals were met in the study. However, sulphur dioxide, carbon monoxide, nitrogen oxides, and particulate emissions standards were exceeded.
- Condensed water from the treatment process required treatment.

Figure 1. Schematic diagram of Tacluk process



STATUS

The information presented in this summary is based on the vendor's report entitled *Treatability Study Report, Pacific Place Soils Remediation Project*, June 1992; and a technical report prepared by Stearns & Conrad Engineers to be published under the DESRT program, entitled *Technical Summary Report for the Pacific Place Special Waste Treatability Study Program.*

Project Summary prepared by Stearns & Conrad Engineers for:
DESRT Program, Technology Development Branch
Conservation & Protection, Environment Canada
Hull, Quebec K1A 0H3

In cooperation with:
B.C. Ministry of Environment, Lands, and Parks

For further information contact:
G. Hardy, Environment Canada (819) 953-0962
B. Ferguson, B.C. Environment (604) 356-6027

Table 1. Summary of Test Results

Contaminant	Sample 1 + Sand		Sample 1,2,4 + Sand		Sample 3		Treatment Goal
	Feed	Treated	Feed	Treated	Feed	Treated	
Total PAHs	46	ND	309	BDL	2	ND	20
Total Chlorophenols	ND	ND	ND	ND	ND	BDL	1
Oil and Grease	118	26	159	<5	1180	21	1000
TEH	145	ND	ND	ND	ND	ND	–

Note: Feed concentrations diluted due to blending with sand
All concentrations are in mg/kg
BDL = Below Detection Limits
ND = Not Detected
TEH = Total extractable hydrocarbons

DISCLAIMER/REVIEW NOTICE
This document has been reviewed by the Technology Development Branch of Environment Canada. The contents do not necessarily reflect the views and policies of agencies represented by DESRT. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

The National Contaminated Sites Remediation Program

DESRT Development and Demonstration of Site Remediation Technology

NEAR-REAL-TIME MONITORING OF CONTAMINATED SOILS

ASL ANALYTICAL SERVICE LABORATORIES LTD.
Vancouver, British Columbia

- PROJECT SUMMARY -

May 1995

INTRODUCTION

In 1989, the Canadian Council of Ministers of the Environment (CCME) acknowledged the need for a consistent, national, approach for the prioritization and remediation of high risk contaminated sites in Canada. In response to this need, the CCME established the National Contaminated Sites Remediation Program (NCSRP), which is supported and administered through federal-territorial bilateral agreements.

The DESRT (Development and Demonstration of Site Remediation Technology) program is a component of NCSRP. It was established to address the NCSRP objective of working with industry to stimulate the development and demonstration of new and innovative technologies with the potential to resolve problems that are critical to the environmental remediation of contaminated sites.

DESRT SUPPORTED WORK

This project involved the demonstration of an enhanced bioremediation treatment technology and the evaluation of near-real-time analytical methods.

A major component of site characterization and remediation projects is the chemical analysis of generated samples which can represent a significant portion of project costs and add appreciably to the time involved in completing the work.

ASL and the Wastewater Technology Centre (WTC) undertook the first phase of this project which involved the evaluation, development, and subsequent demonstration of the following innovative near-real-time (NRT) analytical techniques:

- supercritical fluid extraction (SFE) of polycyclic aromatic hydrocarbons (PAHs) and chlorinated phenolics (CPs) from soils;
- rapid extraction and high pressure liquid chromatography (HPLC/fluorescence) detection of PAHs;
- volatile aromatic hydrocarbon analysis using solid phase microextraction (SPME) techniques;
- immunoassay technology for the determination of PAHs, polychlorinated biphenyls (PCBs), and CPs;
- microwave assisted digestion technology for the rapid determination of trace metals;
- application of X-ray fluorescence spectroscopy (XRF) for rapid determination of trace metals.

Some of the techniques described above were used to analyse samples relating to a separate phase of this project which was conducted by Grace Dearborn and involved the enhanced bioremediation of contaminated soils. Information on the enhanced bioremediation work is published as a separate DESRT Technical Summary Sheet. This project was jointly funded ($ 402 000) by Environment Canada and the B.C. Ministry of Environment, Lands, and Parks under the DESRT program.

TECHNOLOGY DESCRIPTION

Supercritical fluid extraction (SFE) uses extraction solvents such as carbon dioxide and nitrous oxide, in their supercritical states, to extract polycyclic aromatic hydrocarbons and chlorinated phenols from contaminated soils. The technique is complementary to Soxhlet or sonication extraction and requires little organic solvent or tedious manipulations.

The rapid extraction and fluorescence detection of PAHs uses a rapid high temperature extraction process followed by analysis using a dual pump liquid chromatography system coupled to a fluorescence detector for the fast, sensitive and partly selective determination of PAHs in contaminated soils. Current methods usually employ a lengthy extraction, Soxhlet or sonication, followed by HPLC or GC/MS determination.

Solid phase microextraction (SPME) was investigated as an alternative means of detecting volatile aromatic hydrocarbons (BETX) in contaminated soils. The BETX partitions from the soil onto a fused silica fibre which is then removed and the analytes are thermally desorbed in the injector of a gas chromatograph. The technique can be used instead of present purge and trap or headspace methods.

Immunoassay techniques are based on highly selective antigen-antibody interactions and the use of sensitive enzyme reactions to produce analytical results. The test systems are capable of detecting low levels of PAHs, PCBs, and CPs in contaminated soils with minimum sample preparation. The technique does not require Soxhlet or sonication extraction of the soil or sophisticated instrumentation such as gas chromatograph or HPLC.

Microwave assisted digestion techniques use commercial microwave units to effect rapid heating and digestion of contaminated soils. The acid extract is ready in minutes as opposed to the usual overnight hotplate digestion required by current methodologies.

Energy dispersive X-ray fluorescence (EDXRF) uses x-rays to penetrate the soil matrix and excite the metal contaminants. Emitted radiation from the fluorescence of the metals is used to detect and quantify any metals present in the soil. The technique does not require hot acid digestion of the soil and is non-destructive in nature. Some sample preparation, such as drying and homogenization is needed for reproducible XRF results.

TECHNOLOGY DEMONSTRATION RESULTS AND CONCLUSIONS

Supercritical fluid extraction (SFE) operating conditions of pressure, temperature, modifier, and extraction time were optimized after numerous experiments using standard reference soils. The developed SFE procedure can extract eight soil samples per hour with results comparable to traditional extractions which require up to sixteen hours. The technique offers the advantages of speed, increased extraction efficiency, and reduction of hazardous solvents over both Soxhlet and sonication techniques.

Rapid extraction and fluorescence detection studies involved determining optimum chromatographic conditions to achieve good sensitivity and rapid elution profiles for the PAHs. A rapid extraction procedure was developed that used only 100 mg of sample and a total analysis time of 19 minutes. While the procedure is fast and results for total PAHs compare favourably to those obtained by Soxhlet extraction followed by GC/MS, this new technique does not resolve all the individual PAHs.

Solid phase microextraction (SPME) studies included investigating the individual and combined effects of the three parameters: extraction temperature, presence of salt, and acidity. Other experiments compared the results of the standard purge and trap analyses with SPME headspace analyses on the same group of 10 spiked water samples. Two extraction procedures, both utilizing solid phase microextraction techniques, coupled with GC/FID detection were developed for the rapid analysis of volatile aromatic hydrocarbons (BETX) in soils.

Immunoassay techniques Method development work investigated the technical parameters that govern the immunoassay technique and correlating lab and field test results. A number of different immunoassay test kits were field tested at contaminated sites in British Columbia. While their usefulness was site specific, they did provide rapid analytical information when used in the appropriate manner.

Microwave assisted digestion methods were developed by optimizing digestion reagent mixtures and instrument operating parameters. Other factors such as sample size, sample composition, and sample homogeneity were also investigated. Two rapid procedures were developed; one employing concentrated acid mixtures and the second using dilute acid mixtures. In general, the results from microwave assisted digestion were equal to, or superior to, those obtained using conventional acid digestion techniques and the speed of the analysis was greatly enhanced.

Energy dispersive X-ray fluorescence (EDXRF) detection of metals in contaminated soils and reference materials gave results that correlated well with those obtained by more conventional hotplate digestion procedures. EDXRF measurements were found to be affected by sample homogeneity: particle size distribution, moisture content, and varied concentrations of different metals in the soil matrix. A field trial was conducted where 35 samples per day were routinely analysed for 11 different metals. While some metals had poor detection limits, good correlations between field XRF and laboratory means were observed for arsenic, $r=0.81$; copper, $r=0.83$; and lead, $r=0.93$.

STATUS

The laboratory and field demonstration portions of this project have been completed. A technical report is being prepared by ASL Analytical Services Laboratories Ltd. and is expected in early 1995.

FOR MORE INFORMATION

This Technical Summary Sheet was prepared by ASL Ltd. for:
The DESRT Program, Technology Development Directorate
Environmental Protection Service, Environment Canada
Hull, Quebec

In cooperation with:
B.C. Ministry of Environment, Lands and Parks

For further information contact:

L. Keller, Environment Canada (819) 953-0962

J. Ward, B.C. Ministry of Environment, Lands and Parks (604) 387-9951

Disclaimer/Notice Review:

This document has been reviewed by the Technology Development Directorate of Environment Canada. The contents do not necessarily reflect the views and policies of agencies represented by DESRT. Mention of trade names or commercial products does not constitute a recommendation or endorsement for use.

The National Contaminated Sites Remediation Program

DESRT Development and Demonstration of Site Remediation Technology

APPLICATION OF TALLON TECHNOLOGY IN THE DICKSON REMEDIATION PROJECT, BOMBARDIER INC., MONTRÉAL, QUÉBEC

- PROJECT SUMMARY -

September 1995

INTRODUCTION

In 1989, the Canadian Council of Ministers of the Environment (CCME) established the National Contaminated Sites Remediation Program (NCSRP), which is supported and administered through federal-provincial-territorial bilateral agreements.

The DESRT (Development and Demonstration of Site Remediation Technology) program was established to address the NCSRP objective of working with industry to stimulate the development and demonstration of new and innovative technologies having the potential to resolve problems which are critical to the environmental remediation of contaminated sites.

DESRT SUPPORTED TECHNOLOGY

Tallon Metal Technologies Inc.'s soil treatment technology was developed between 1987 and 1991 employing portions and adaptations of its technology which had been developed for the recovery of heavy metals from wastewater and heavy metal wastes from the mining industry. The technology is an integration of materials handling procedures as employed in the minerals processing industry and as adapted to soil treatment by Tallon with the hydrometallurgical and other physico-chemical recovery techniques which Tallon had developed for selective recovery of heavy metals and organic contaminants from soil and other wastes.

The DESRT Program first supported a treatability study to evaluate and adapt the treatment process for the soil of the Dickson site. Following this study, a pilot demonstration project was completed using a 300 t/d capacity unit.

The project was financed jointly by Environment Canada, the Ministère de l'Environnement et de la Faune du Québec and Bombardier Inc. The total cost for the project was 880 000 $. The DESRT program contribution was 250 000 $.

CONTAMINATION CHARACTERISTICS

Tallon's technology was applied during the environmental remediation of the Dickson site, located in Montreal East. Historically this property was a part of the MLW Bombardier industrial site, used since the beginning of the century for railroad material production.

Characterization studies carried out between 1989 and 1992 revealed that the site was contaminated with copper, lead and arsenic. After a study of the options, an excavation and treatment process using Tallon's Technology was chosen to restore the soil quality.

PROJECT DEMONSTRATION SUMMARY

The results of the treatability studies with soils from the Dickson site permitted the construction of a process flow sheet, as shown in Figure 1, suited to this soil type and contamination level. Extraction and recovery processes were replaced with a flotation separation process. The main stages of the Tallon technology that were applied to this project were:

- After excavation, contaminated soil is delivered to a 5 cm vibrating screen.
- Soil (< 5 cm) is added to a feed hopper and discharged on a conveyor where metallic debris are recovered with a magnetic head pulley.
- Non-metallic material is discharged onto a vibrating screen (0,6 cm) where it is washed.
- Soil (< 0,6 cm) is washed directly into double-cell attrition scrubbers where soil particles are scrubbed mechanically.
- The discharge of the attrition scrubbers is passed through a magnetic purifier. Non magnetic material is discharged directly in a spiral classifier where the coarse materials (> 0,2 mm) are removed. The overflow containing finer particles (< 0,2 mm) is delivered to flotation cells.
- The heavy metal enriched float is directed to a plate filter press where the contaminated solids are collected.
- The underflow containing non-contaminated suspended particles is directed to a belt filter where the solids are washed and dewatered.

In order to verify the effectiveness of the treatment, samples were taken periodically at various stages of the process. The samples taken at each control point were as follows:

- point A: contaminated soils before sieving
- point B: coarse materials (> 5 cm)
- point C: materials under 5 cm in diameter
- point D: treated materials
- point E: fine materials leaving the filter press
- point F: process water
- point M: metallic debris leaving the magnetic separators.

TECHNOLOGY DEMONSTRATION RESULTS

The analytical results are summarized in Table 1; mean concentrations of arsenic, copper and lead are given for each control point. The results and comments are given for two excavation sites because of the significant difference between the type of fill found at each. The major conclusions of the study are summarized hereafter.

- Site remediation was carried out in accordance with the selected procedure to eliminate a potential source of pollution and restore the site to an acceptable environmental standard for industrial use.
- Analysis results revealed that the concentrations of metals and organic products in the process water were low and corresponded to Montreal Urban Community standards for disposal into the combined sewer system.
- From a technical standpoint, the equipment operated effectively for granular soil (non-cohesive). All problems linked primarily to integrating several types of equipment into a treatment system were resolved, mostly during the start-up phase.
- The project revealed a major operating problem related to certain pieces of equipment due to the presence of cohesive soil (silt and clay) in Site I. Although the utilization of a primary scrubber and modified screen had been successfully demonstrated in a previous project for a different soil containing > 50% clay, there was insufficient time to institute the equipment modifications for the Dickson site due to project timing constraints.
- Magnetic separation made it possible to recover material with a high arsenic concentration on Sites I and II and with a high copper concentration primarily on Site II;
- The results of the analysis of the treated soil demonstrate the system effectiveness in reducing arsenic contamination, with over 82% of samples having concentrations lower than criterion "B" at Site I, where more arsenic contamination was found, and 100% of samples having concentrations lower than criterion "C"; the mean concentration at the same site dropped from 52.4 mg/kg (control point A) to 25.1 mg/kg (control point D);
- Physicochemical separation in the flotation system made it possible to concentrate arsenic and copper. The effectiveness of flotation seemed to increase when higher concentrations were present in the soil to be treated.

FOR MORE INFORMATION

The project was carried out by Tallon Metal Technologies Inc. with the collaboration of Ecotone Inc. and Bombardier Inc.

The information provided in this summary is based on a technical report produced in October 1993 by Écotone inc., volumes 1 and 2, entitled: Application de la technologie Tallon dans le cadre du projet de réhabilitation du site Dickson, Montréal.

For more information, please contact:

Technology Development Section, Environment Canada (514) 283-9678

Direction de la coordination de la recherche, Environnement et Faune du Québec (418) 643-2073

Figure 1. Process Schematic

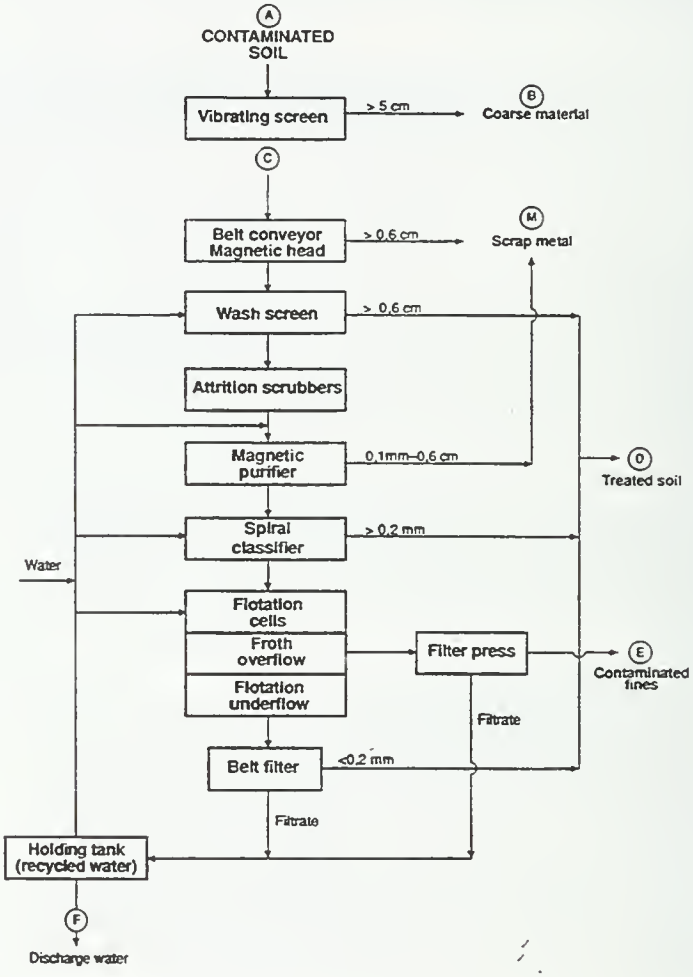


Table 1. Mean concentrations (mg/kg) of metals at each control point

	Criteria (MEF)		SITE I Control Point						SITE II Control Point					
	B	C	A	B	C	M	D	E	A	B	C	M	D	E
As	30	50	52,4	65,7	50,8	70,0	25,1	97,1	27,4	15,1	21,3	79,7	14,3	24,2
Cu	100	500	151,4	204,8	313,6	420,9	115,5	921,8	260,6	365,6	235,8	822,6	346,6	555,0
Pb	500	1000	248,0	213,2	220,2	277,2	187,6	434,1	336,2	283,5	282,0	928,7	327,3	564,8

DISCLAIMER/REVIEW NOTICE

This document has been reviewed by DESRT Federal-Provincial Comite for the Québec Region. The contents do not necessarily reflect the views and policies of agencies represented by DESRT. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

The National Contaminated Sites Remediation Program

DESRT Development and Demonstration of Site Remediation Technology

APPLICATION OF THE PYROVAC VACUUM PYROLYSIS TECHNOLOGY FOR THE REMEDIATION OF CONTAMINATED SOILS FROM "LE VIDANGEUR DE MONTRÉAL INC." SITE, MASCOUCHE, PROVINCE OF QUÉBEC LAVAL UNIVERSITY/INSTITUT PYROVAC INC.

- PROJECT SUMMARY -

September 1995

INTRODUCTION

In 1989, the Canadian Council of Ministers of the Environment (CCME) established the National Contaminated Sites Remediation Program (NCSRP), which is supported and administered through federal-provincial-territorial bilateral agreements.

The DESRT (Development and Demonstration of Site Remediation Technology) program was established to address the NCSRP objective of working with industry to stimulate the development and demonstration of new and innovative technologies having the potential to resolve problems which are critical to the environmental remediation of contaminated sites.

DESRT SUPPORTED TECHNOLOGY

The Pyrovac™ vacuum pyrolysis process was developed by Pyrovac International Inc. and is one of the innovative technologies which was chosen by the DESRT program. The investigation was carried out by Laval University in collaboration with Pyrovac Institute Inc. and was supported by Environment Canada and the ministère de l'Environnement et de la Faune du Québec.

The DESRT Program supported an investigation into the feasibility of the vacuum pyrolysis process for the treatment of soil samples with varying levels of hydrocarbon contamination, originating from the "Le Vidangeur de Montréal inc" site in Mascouche (Québec). The contribution provided by the DESRT Program was $221 430.

CONTAMINATION CHARACTERISTICS

The "Le Vidangeur de Montréal inc." site is located in Mascouche (Qc), 20 km northeast of Montréal and has a surface area of 6 km². The site, previously a sand-quarry, was used from 1969 to 1974 for the dumping of solid residues, as well as for the incineration of petroleum sludges. Fissured basins containing liquids and hydrocarbon sludges were abandoned. Today, hydrocarbon tar slabs can be found in several places on the site whose soil and water have been contaminated with hydrocarbons, polycyclic aromatic hydrocarbons and polychlorinated biphenyls. The orphan site is considered highly contaminated according to Québec norms.

PROJECT DEMONSTRATION SUMMARY

The reactor used in this study is a horizontal cylindrical vessel equipped with a novel mechanism for soil handling in the reactor which ensures maximum heat transfer. The contaminated soils are pyrolyzed, ie. heated to a temperature of about 500°C in the absence of oxygen. The total pressure is about 35 kPa. The organic matter evaporates and forms vapours. These vapours are pumped out of the reactor and condensed as an oily phase and an aqueous phase in two condensors operating in series. The residual non-condensable gas is used as a make-up heat source in the process. A nitrogen air-tight system prevents air from entering the reactor. The restored soils are continuously recovered and cooled.

The samples collected at the Mascouche site were chosen so as to represent a variety of types of soils (sand, clay, tar slabs) and a variety of contamination concentrations. The objectives of the treatment were to reduce the level of organic contamination so as to respect the Québec criteria for soil contamination.

Initially, laboratory scale batch runs were carried out in a vacuum pyrolysis reactor. Ten samples of 3 to 10 kg (total of 75 kg) were treated. These runs confirmed the potential of the vacuum pyrolysis concept since all the treated soil samples matched the residential level A criterion.

The investigation was thus continued with the development of the process on an industrial prototype unit. The pilot unit with a central reactor 3 m long and 0.6 m in diameter was constructed and tested. The satisfactory mechanical operation of the unit was demonstrated with the treatment of a contaminated soil sample at a flowrate of 75 kg/h.

The analyses carried out on the sample treated with the pilot unit indicated concentrations corresponding to residential criterion.

A preliminary techno-economic evaluation was carried out based on the engineering data provided by operation of the industrial prototype. The hypothesis of a 5 t/h unit was made and the corresponding construction costs were evaluated at $ 700 000, excluding the transportation equipment.

The operating costs did not include the treatment of the aqueous phase; however, they did include an evaluation of the costs associated with mobilization and demobilization. The latter are expected to be low, since future installations will be mobile and of little bulk.

The treatment cost per ton of contaminated soil has been evaluated at $50 (excluding the cost for the treatment of the aqueous phase and equipment depreciation).

TECHNOLOGY DEMONSTRATION RESULTS

The table below provides the concentration of contaminants in the soils before and after treatment, for both the laboratory vacuum pyrolysis runs as well as the pilot scale run. The following major conclusions were reached in this study:

- Production of a reuseable by-product (oils).
- Residential criterion reached for the treated soils.
- Applicable to many types and combinations of hydrocarbons.
- The polychlorinated biphenyls are extracted from the soils and are concentrated in the oils.
- Negligible atmospheric emissions and no gas cleaning equipment required.

Potential

- The operating conditions can be adjusted for the treatment of various degrees of contamination and moisture of the different soil samples. This allows for the adjustment of the energy consumption and the optimization of the treatment capacity.
- The unit can be loaded onto a mobile system in order to operate directly on the site. The design of this system is presently being investigated.
- The preliminary economic evaluation is favourable and compares well with technologies already available.

Limitations

- The aqueous phase produced during the process must be subsequently treated (possibly together with the water on site).
- The electric heating system presently used does not allow the pilot unit to be operated to its optimum capacity. Future studies are planned to test other modes of heating.
- Future investigations should be carried out to study the treatment of different types of soils.

FOR MORE INFORMATION

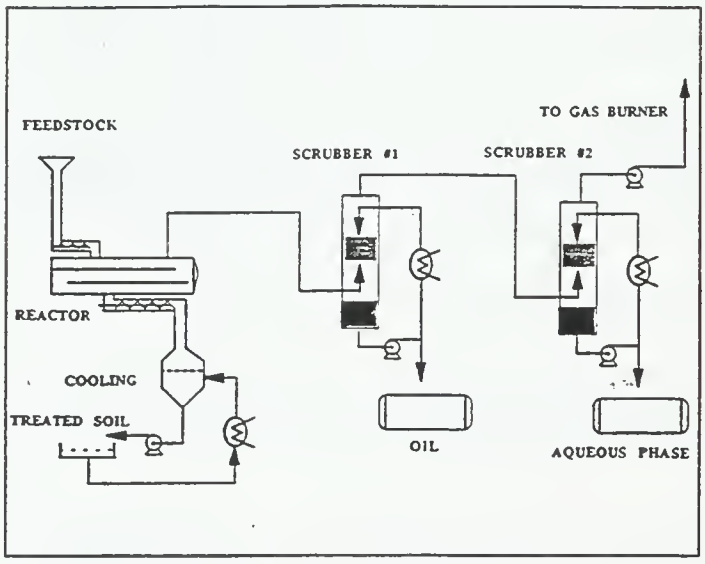
The project was carried out by Laval University with the collaboration of Pyrovac Institute Inc.

The information provided in this summary is based on a technical report produced in September 1993 by Laval University with the collaboration of Pyrovac Institute Inc., entitled: Évaluation du procédé Pyrovac de pyrolyse sous vide pour la restauration des sols contaminés avec des matières organiques dangereuses.

For more information, please contact:

Technology Development Section,
Environment Canada (514) 283-9678

Direction de la coordination de la recherche,
Environnement et Faune du Québec (418) 643-2073



Sample	Petroleum hydrocarbons (mg/kg, anhydrous basis)	
	BEFORE	AFTER
Clay A	290	5.0
Clay B	150	4.1
Sand A	3 000	6.8
Sand B	6 100	4.9
Sand C	19 770	2.9
Sand D	2 050	7.7
Sand E	790	3.1
Sand F	4 600	2.5
Tar slab A*	51 000	12.2
Tar slab B*	49 000	236.0
Sand (pilot unit)	7 470	22.0

* Tar slabs on the surface

DISCLAIMER/REVIEW NOTICE

This document has been reviewed by DESRT Federal-Provincial Comite for the Québec Region. The contents do not necessarily reflect the views and policies of agencies represented by DESRT. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

The National Contaminated Sites Remediation Program

DESRT Development and Demonstration of Site Remediation Technology

IN SITU REMEDIATION OF SOILS BY VENTING AND FORCED AERATION SHELL SERVICE STATIONS IN VANIER AND SOREL, QUÉBEC

- PROJECT SUMMARY -

September 1995

INTRODUCTION

In 1989, the Canadian Council of Ministers of the Environment (CCME) established the National Contaminated Sites Remediation Program (NCSRP), which is supported and administered through federal-provincial-territorial bilateral agreements.

The DESRT (Development and Demonstration of Site Remediation Technology) program was established to address the NCSRP objective of working with industry to stimulate the development and demonstration of new and innovative technologies having the potential to resolve problems which are critical to the environmental remediation of contaminated sites.

DESRT SUPPORTED TECHNOLOGY

The technology in question is an *in situ* treatment method that combines the venting of unsaturated subsurface soils with forced aeration, produced by injecting air into the soils located beneath the water table. The DESRT program sponsored the demonstration of this technology at two sites, one in Vanier and the other in Sorel. The performance of the Forced Aeration and Ventilation System (FAVS) was evaluated primarily in terms of the remediation of soils in relation to the "C" criteria of Environnement et Faune Québec. The potential for reducing the concentrations of dissolved hydrocarbons in the ground water was also examined.

The project was financed by Shell Canada Products Ltd., Environment Canada and Environnement Québec. The total cost of the project was $366,600 and the DESRT contribution was $120,000. ADS Groupe-Conseil Inc. provided complete technical expertise for the project.

CONTAMINATION CHARACTERISTICS

The project was carried out as part of the remediation of two former service station sites in the respective cities of Vanier and Sorel, Québec. Previous characterization studies revealed that the soils were contaminated with light hydrocarbons.

The preliminary characterization studies indicated that at the Vanier site, the water table was 7 m beneath the surface in the unit of fine, silty sand with thin layers of silt. The hydraulic conductivity was estimated at 10^{-4} cm/s. The volume of soil affected was 3,000 m³ and the mass of hydrocarbons was estimated at 3,000 kg. At the Sorel site, the water table was between 2.5 and 3.0 m beneath the surface. The subsurface soils were composed of fine sand with a small amount of silt and had a hydraulic conductivity of 10^{-4} cm/s. Approximately 300 m³ of soil was contaminated with 300 kg of hydrocarbons at this site.

PROJECT DEMONSTRATION SUMMARY

This technology uses air injection wells, located under the water table, to force the volatilization of the soil contaminants contained within the saturated zone. The injection of air beneath the water table increases the migration of vapours towards the surface. Ventilation wells then draw off the vapours and extract volatile contaminants contained in the soils located in the unsaturated zone.

The process consists of a ventilation and treatment system and an injection system (Figure 1). The injection and ventilation apparatus have underground components (screened pipes and control valves) and mechanical components, including a water trap hooked up to a pump to control water accumulation, a dust-control filter, a vacuum pump and two activated charcoal drums connected in series. The injection system is composed essentially of a compressor preceded by an air filter and followed by a safety valve and control valves. All mechanical components, including the activated charcoal drums, are mounted in small metal containers measuring 2.4 m wide by 4 m long (Sorel) and 2.4 by 5 m long (Vanier) to facilitate transportation of the units from one site to another. The containers are insulated such that the noise heard at a distance of 15 m (adjacent buildings) blends in with the ambient noise levels.

In Vanier, the FAVS was comprised of nine ventilation wells and eight injection wells. The service station continued operations during the remediation. The system was operated in ventilation mode with a nominal air flow of 7.1 m³/min. Air was injected at half that rate (3.7 m³/min).

In Sorel, the FAVS was composed of four horizontal ventilation wells and three vertical injection wells. The system was operated in ventilation mode with a nominal air flow of 2.7 m³/min. Air was injected at a rate of 1.7 m³/min.

In both cases, the concentration of VOCs (total volatile organic compounds) was measured in order to quantify the mass of hydrocarbons extracted and to verify the concentrations passing through the charcoal filters. The performance of the FAVS was thus evaluated on the basis of the physical extraction of the compounds, without taking account of other factors that could play a role in the remediation process (biodegradation, etc.)

TECHNOLOGY DEMONSTRATION RESULTS

The results of the FAVS treatment for both sites are summarized in the table below. The main conclusions are as follows:

- The mass of contaminants directly extracted by FAVS (physical extraction) was approximately 45% of the initial mass based on a treatment period of 110 days at the Vanier site and 475 days at the Sorel site (40% had already been extracted after the first 200 days.)
- The volume of soil affected (exceeding "C" criteria) both above and below the water table was reduced by 94% (from 3,000 m³ to 170 m³ at the Vanier site) and by 83% (300 m³ to 50 m³ at the Sorel site) following treatment.
- Other factors contribute to reducing the mass of hydrocarbons in the soil in a proportion that could be equivalent to physical extraction. These include increased biodegradation due to the injection of air and direct volatilization during excavation, the removal of reservoirs, and the installation of conduits in the excavation trenches.

A follow-up of the ground water quality revealed that hydrocarbons in the dissolved phase are present essentially at the surface of the water table. Moreover, the change in concentrations seems to indicate an improvement as a function of treatment time. However, the process is long and residual concentrations in saturated soils, although below the "B" criteria, are high enough to affect the water, leading to concentrations exceeding the MEF's "C" criterion for ground water.

	Vanier	Sorel
Concent, of total BTEX (mg/kg)		
Initial	20-850	15-1130
At end of treatment period	ND-165	ND-590
Number of days of treatment	110	475
Mass Balance		
Initial hydrocarbon mass	3000 kg (100 %)	300 kg (100 %)
Mass extracted by FAVS	1300 kg (43 %)	130 kg (43 %)
Mass excavated	50 kg (2 %)	-
Remaining mass (soils<C)	200 kg (7 %)	50 kg1 (17 %)
Biodegraded or volatilized mass	120 kg (40 %)	1450 kd (48 %)

NOTES
ND: Under the detection threshold.
1: 50 m³ of soil still exceeded MEF "C" criterion after the treatment period.

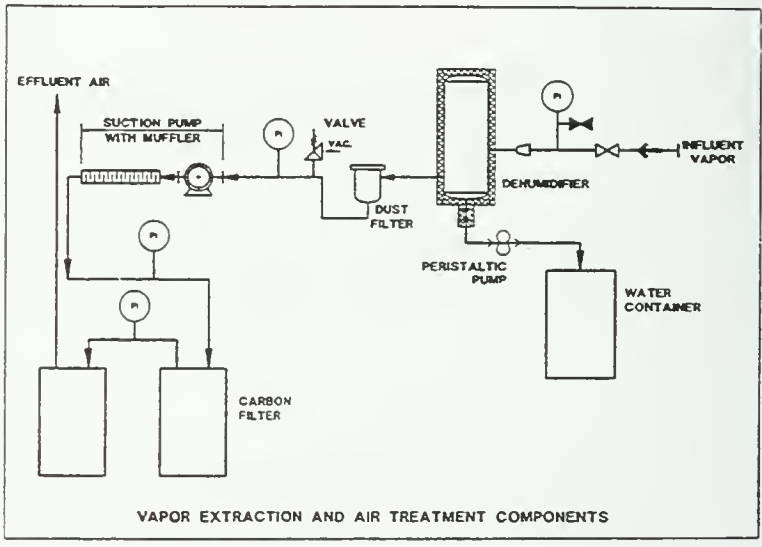
FOR MORE INFORMATION

The project was carried out by Shell Canada Products Ltd. in cooperation with ADS Groupe-Conseil Inc.

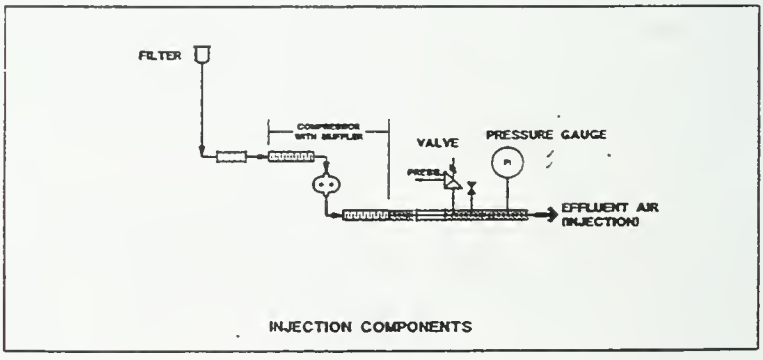
The information provided in this summary sheet is based on technical report prepared by ADS Groupe-Conseil Inc. entitled: "Restauration *in situ* des sols par un système de ventilation et d'aération forcée. Projet de développement technologique, Stations-service Shell. Vanier et Sorel".

For more information, please contact:

Technology Development Section,
Environment Canada (514) 283-9678
Direction de la coordination de la recherche,
Environnement et Faune du Québec (418) 643-2073



VAPOR EXTRACTION AND AIR TREATMENT COMPONENTS



INJECTION COMPONENTS

FIGURE 1

DISCLAIMER/REVIEW NOTICE

This document has been reviewed by DESRT Federal-Provincial Comite for the Québec Region. The contents do not necessarily reflect the views and policies of agencies represented by DESRT. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

The National Contaminated Sites Remediation Program

DESRT Development and Demonstration of Site Remediation Technology

DEVELOPMENT AND DEMONSTRATION OF A BIOFILTRATION PROCESS BIOGÉNIE INC., PROVINCE OF QUÉBEC

- PROJECT SUMMARY -

eptember 1995

INTRODUCTION

n 1989, the Canadian Council of Ministers of the Environment (CCME) established the National Contaminated Sites Remediation Program (NCSRP), which is supported and administered through ederal-provincial-territorial bilateral agreements.

The DESRT (Development and Demonstration of Site Remediation Technology) program was established to address the NCSRP objective of working with industry to stimulate the development and demonstration of new and innovative technologies having the potential to resolve problems which are critical to the environmental remediation of contaminated sites.

DESRT SUPPORTED TECHNOLOGY

The project objective was to develop a biological process to treat gases during the remediation of gasoline-contaminated soil. The project was initiated in February 1993 and ended in October 1994.

Biogénie inc. is the project proponent. Work was carried out in cooperation with the National Research Council of Canada. Project financing was provided by the DESRT program and Biogénie inc. The DESRT contribution amounted to 314 000$ of the total 654 111$ project expenditures.

CONTAMINATION CHARACTERISTICS

During the replacement of an underground storage tank at a service station on the outskirts of Québec City, gasoline was observed to have leaked and contaminated surrounding soil. Field tests were conducted and the contaminated area was estimated to be 250 m² requiring the treatment of approximately 400 cubic meters. The soil was located at an average depth of 3 meters. In situ treatment (bioventing and air sparging) was carried out at the remediation site. Bore holes were drilled in order to both inject air into the contaminated soil and recover effluent gases for treatment. The waste gas recovered contained large quantities of volatile hydrocarbons including benzene, toluene and xylene compounds. The treatment system for these gases had to be highly efficient due to the close proximity of restaurants, boutiques and a bus stop.

PROJECT DEMONSTRATION SUMMARY

The system schematically set forth in figure 1 was made up of three units: an air/water separator, a trickling filter reactor and a biofiltrer.

Waste gas was first drawn in through the air/water separator used to remove impurities in the air such as water droplets, solid particles, etc. The effluent then travelled through the trickling filter reactor packed with a very porous polymer. Gas purification was obtained by soaking the liquid percolating through the polymer bed against a back-flow of gas. The use of a polymer as the packing material enhanced mass transfers between the liquid and the gas. Moreover, the polymer could fix a large concentration of specific bacteria helpful in degrading the contaminants found in the liquid phase. Following treatment in the trickling filter reactor, the waste gas was channelled to the compost-based biofilter where residual contaminants were removed by the compost bed.

Testing was carried out at the site during a five-month period. During the start-up phase, a liquid containing mineral nutrients and an emulifying agent was introducted into the trickling filter unit. The bed was inoculated with volatile hydrocarbon-degrading bacteria. Biologically active compost-based material was utilized as the biofilter bed. During the system's operation, water nutrients and emulsifiers were added to maintain optimum operational parameters. Analytic follow-up was conducted (physical, chemical, biochemical and microbiological) to evaluate system performance.

TECHNOLOGY DEMONSTRATION RESULTS

Table 1 indicates the results obtained in benzene, toluene and xylene compound elimination.

Test results substantiate the following conclusions:

1. The system is made up of a mobile units and is easy to use (transport, install and operate).
2. It functions under variable ambient temperatures (4 seasons).
3. It is efficient in the treatment of gases contaminated by volatile hydrocarbons such as benzene, toluene and xylene compounds.
4. It may be used in the treatment of other kinds of contaminants, can tolerate high contaminant concentrations, and requires a minimal amount of time to start up.

Table I
Removal of benzene, toluene and xylenes

Contaminant	Concentration before treatement (mg/m^3)	% of removal
Benzene	1 - 104	87.3
Toluene	6 - 227	92.5
Xylenes	9 - 56	90.1

FOR MORE INFORMATION

The project was carried out by Biogénie Inc. with the collaboration of National Research Council Canada.

The information provided in this summary is based on a technical report prepared by Biogénie Inc., entitled: Développement et démonstration d'un procédé de biofiltration.

For more information, please contact:

Technology Development Section,
Environment Canada (514) 283-9678

Direction de la coordination de la recherche,
Environnement et Faune du Québec (418) 643-2073

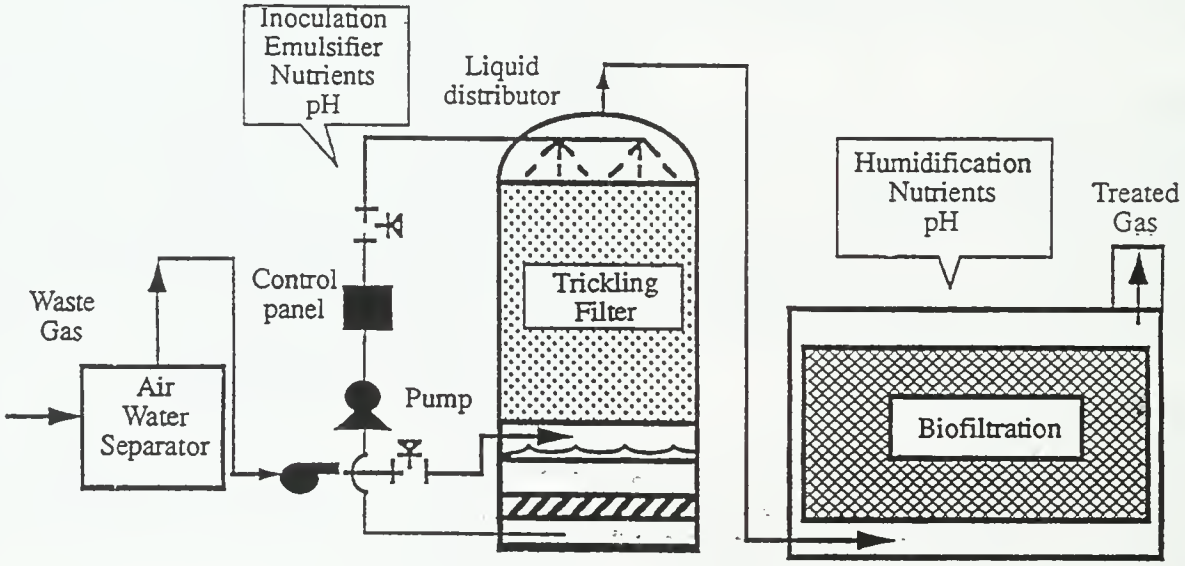


Figure 1: Biological treatment system of waste gas

DISCLAIMER/REVIEW NOTICE

This document has been reviewed by DESRT Federal-Provincial Comite for the Québec Region. The contents do not necessarily reflect the views and policies of agencies represented by DESRT. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

The National Contaminated Sites Remediation Program

DESRT Development and Demonstration of Site Remediation Technology

BIOREMEDIATION OF SOIL CONTAMINATED BY TRANSFORMER OIL (BOUCHERVILLE) AND DIESEL FUEL (JONQUIÈRE) BIOGÉNIE INC., QUÉBEC

- PROJECT SUMMARY -

September 1995

INTRODUCTION

In 1989, the Canadian Council of Ministers of the Environment (CCME) established the National Contaminated Sites Remediation Program (NCSRP), which is supported and administered through federal-provincial-territorial bilateral agreements.

The DESRT (Development and Demonstration of Site Remediation Technology) program was established to address the NCSRP objective of working with industry to stimulate the development and demonstration of new and innovative technologies having the potential to resolve problems which are critical to the environmental remediation of contaminated sites.

DESRT SUPPORTED TECHNOLOGY

The present project undertaken between May 1992 and May 1993, was carried out within the framework of the federal-provincial Development and Demonstration of Site Remediation Technologies Program (DESRT). It intended to demonstrate the potential and limitations in the use of a biopile treatment process to treat soils contaminated by certain types of hydrocarbons, particularly transformer oil (Boucherville site) and diesel fuel (Jonquière site). At each of the two sites, treatment was carried out on 500 cubic metres of soil.

The project objectives were to:

1. Verify the importance of volatilization and leaching during the biological degradation process.
2. Establish the treatability potential (using biological means) of the two types of contamination: soil contaminated by transformer oil and soil contaminated by diesel fuel.
3. Demonstrate the advantages of inoculating adapted bacteria to maximize the biological treatment yield.
4. Confirm the efficiency of the gas evacuation and filtration system.
5. Validate the feasibility of using a biological process within the context of Québec's climatic conditions.
6. Assess the technical and economic aspects of this type of procedure.

The project was financed jointly by "Environment Canada", the "ministère de l'Environnement et de la Faune du Québec" and Biogénie inc. The total cost for the project was of $230 000. The DESRT program contribution was $180 000.

CONTAMINATION CHARACTERISTICS

Diesel fuel and transformer oil are widespread contaminants in Québec. Faced with increasingly stringent legislation governing the replacement of underground reservoirs and the remediation of contaminated sites, the development of technological solutions maximizing environmental benefits, at reasonable cost, is fast becoming an essential requisite. The Boucherville project represented an inappropriate case of soil (clay) and the Jonquière project, a case of high contamination (>50 000 mg/kg of mineral oils and greases).

PROJECT DEMONSTRATION SUMMARY

The process, patented by Biogénie inc. in the United States and in Canada, involves optimizing the biological degradation conditions of the contaminants in the soil:

- The contaminated material is excavated and piled on an asphalt area;
- Perforated pipes are installed under the pile and connected to a suction booster.
- Air drawn from the pile is processed by a treatment system (activated charcoal or biofilter) prior to its release into the atmosphere.
- An irrigation system installed on the surface ensures correct humidity levels. The leachate is recirculated (closed-circuit).
- The soil is mixed periodically and the nutrient inflow (N, P, K) controlled.
- Following treatment, the soil may be returned to its original location, used as filter material at another industrial site or at landfill sites.

TECHNOLOGY DEMONSTRATION RESULTS

Removal of Mineral Oil and Grease

In the Boucherville case study, contaminant concentration was reduced from 13,700 mg/kg to 3,800 mg/kg, a removal rate of 72%. Treatment was continued for 48 weeks, half of which was conducted during the winter. The air was heated and blown under the pile of soil during the cold season.

In the Jonquière Case study, contamination was reduced from 54,100 mg/kg to 17,100 mg/kg during the treatment period which was discontinued after 28 weeks.

The Effects of Inoculation

A section of the pile in Jonquière was inoculated during the course of the treatment with certain bacteria and the results obtained did not demonstrate the effectiveness of such a procedure.

The Effects of the Amendment

A section of the pile in Boucherville was amended with peat moss and wood shavings to enhance soil structure and permeability. An appraisal

of this procedure demonstrated an increase in hydrocarbon removal rates by a factor of 20%.

Mass Balance

The mass balance was calculated for the Jonquière project:

Contaminants initially present in the pile:	35,198.0 kg
Contaminants removed in the course of treatment:	24,031.0 kg
– by volatilization	139.4 kg
– by biodegradation	23,943.6 kg

Potential

- Adaptability: a technology which may be implemented in urban and residential areas, outlying regions, on–site or elsewhere, etc.
- No by–products (no liquid or other types of residue).
- Simultaneous degradation of secondary organic contaminants in the soil.
- Once the soil is treated, there is no hydrocarbon odour and no leachate.
- Significantly lower cost (~ $90/m³) than most other choices, such as membrane encapsulated landfill or thermal treatment.

Limitations

- Difficulty in attaining the decontamination criteria ("A–B" or"B–C") in highly contaminated soils (>20,000 mg/kg of mineral oils and greases).
- Relatively long treatment period in certain cases (between 18 and 40 weeks), for example, soils with high contents of clay.

Conclusion

The project demonstrated that the procedure is efficient in reducing contamination by diesel fuel or transformer oil by approximately 70% under nordic climatic conditions. In most cases of contamination (averaging 20,000 mg/kg or less), the process culminates in B–C range results (1000-5000 mg/kg). By optimizing the control of certain operational parameters, a 75% or better removal rate could have been attained. At the end of the treatment, the soil is biologically stable, free of hydrocarbon odours and no longer leaches contaminants. The cost of applying this technology is estimated at $90 per cubic metre and includes all operations, from the initial excavation of the contaminated soils and their return following treatment.

FOR MORE INFORMATION

The project was carried out by Biogénie inc.

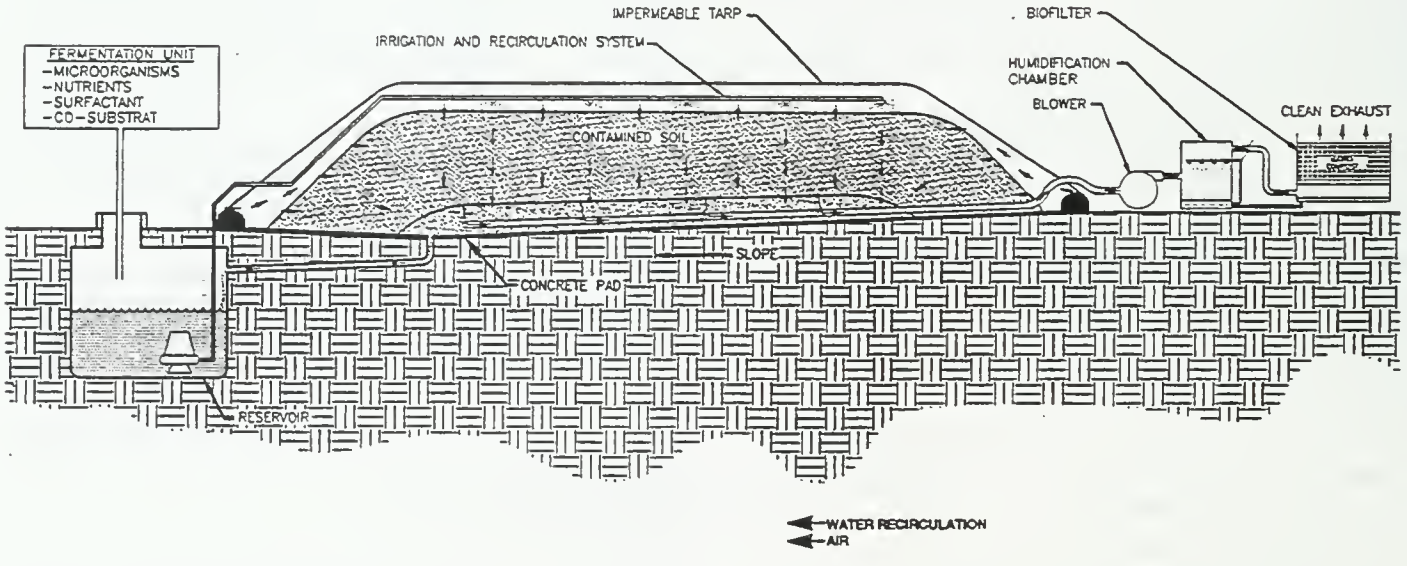
The information provided in this summary is based on a technical report produced in October 1993 by Biogénie inc., entitled: Biotraitement de sols contaminés par des huiles de transformateurs (Boucherville) et par des huiles diesels (Jonquière).

For more information, please contact:

Technology Development Section, Environment Canada **(514) 283-9678**

Direction de la coordination de la recherche, Environnement et Faune du Québec **(418) 643-2073**

SOIL TREATMENT STATION
PROCESS DIAGRAM



DISCLAIMER/REVIEW NOTICE

This document has been reviewed by DESRT Federal-Provincial Comite for the Québec Region. The contents do not necessarily reflect the views and policies of agencies represented by DESRT. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

The National Contaminated Sites Remediation Program

DESRT Development and Demonstration of Site Remediation Technology

DEMONSTRATION OF A BIOTREATMENT TECHNOLOGY USING BIOLYSIS™ AND DREDGING, MANSONVILLE, QUÉBEC SANEXEN ENVIRONMENTAL SERVICES INC.

- PROJECT SUMMARY -

September 1995

INTRODUCTION

In 1989, the Canadian Council of Ministers of the Environment (CCME) established the National Contaminated Sites Remediation Program (NCSRP), which is supported and administered through federal-provincial-territorial bilateral agreements.

The DESRT (Development and Demonstration of Site Remediation Technology) program was established to address the NCSRP objective of working with industry to stimulate the development and demonstration of new and innovative technologies having the potential to resolve problems which are critical to the environmental remediation of contaminated sites.

DESRT SUPPORTED TECHNOLOGY

Biolysis™, a patented technology owned and developed by Sanexen, proceeds by the extracellular attack and transformation of hydrocarbons present in the target matrix, allowing a high rate of degradation for contaminants that are normally resistant to conventional biotreatment techniques. Initially developed using oily sludges from petroleum refineries, the process was adapted in 1992 to deal with contaminated soils and sediments. The process lends itself to applications in the liquid or solid phase, using bioreactor or composting systems. The technology focusses on making largely insoluble compounds such as mineral oils physically, chemically and biologically available for microbial use and subsequent mineralization.

The DESRT program supported the demonstration of the technology as applied to the in-situ remediation of contaminated sediments. 1350 m³ of sediments were decontaminated in a project that was performed in the summer of 1993 at a site in Mansonville in the Eastern Townships region of Quebec.

The project was financed jointly by Environment Canada, the Ministère de l'Environnement et de la Faune du Québec, Huntsman Chemical Company of Canada Inc. and Sanexen Environmental Services Inc. The total cost for the project was 200 700$ and the DESRT contribution was 61 200$.

CONTAMINATION CHARACTERISTICS

A basin, with a natural soil bottom, had received effluents from a polystyrene manufacturing plant between 1975 and 1989. With a new water treatment facility in operation, the basin was decommissioned and the site had to be restored to an environmentally acceptable condition. 1350 m³ of sediments were contaminated at an average concentration of 13 500 mg/kg of mineral oil and grease on a dry weight basis, hydrocarbons being mostly in the range of C17 to C30. No decontamination by heavy metals nor by halogenated substances was involved in this project.

PROJECT DEMONSTRATION SUMMARY

A review of possible remediation technologies indicated that biotreatment followed by solidification offered the best potential in terms of a cost-benefit analysis. The partners used this project to carry out biotreatment in a manner as extensive as possible using the innovative approach proposed by Sanexen and to avoid having to resort to the solidification of leftover contaminants.

Processing took place in-situ over a period of ten weeks using a hydraulic dredge together with aeration and mixing equipment to induce the required extracellular reactions and promote the desired endocellular degradation. Following completion of treatment and of testing, the basin was drained and backfilled.

TECHNOLOGY DEMONSTRATION RESULTS

Microscopic observation revealed that the operational strategies used in the field, namely the method of acclimatization and the control of mechanical shearing, emulsification, pH and of the cycle of dissolved oxygen, were successful in detaching oil from the solid particules, breaking down the droplets to a smaller size and in inducing hydrolysis and cracking of the hydrocarbons as evidenced by the change in the colour of the oil.

It was observed that coarser particules were washed clean in the first week or two of operation. This in fact created difficulties in obtaining representative samples, since the time and location of sampling greatly influence the grain size distribution, and therefore the contamination levels in the samples. Sampling procedures had to be modified from grab sampling during operation to composite sampling following a period of shutdown to insure overall representativeness.

A rate of biochemical degradation of 340 mg/kg-day was achieved in the first four weeks of operation, the rate thereafter leveling to less than 50 mg/kg-day. This compares to a natural degradation rate of 3 mg/kg-day, as estimated from the disappearance rate between the 1989 and 1993 characterization campaigns.

After ten weeks of operation, the two clean-up objectives of the project were met, namely the "B" criterion (1000 mg/kg) and the Quebec waste leachate criterion (30 mg/L) for mineral oil and grease, average concentrations of 920 mg/kg and of 0,3 mg/L having been attained respectively. The technology also met the project's economic objectives with cost of remediation totalling $75 per metric ton of treated material.

Research was also conducted at the Department of Chemical and Biochemical Engineering of the University of Western Ontario to evaluate the nature and effects of biosurfactants in the process, using samples taken at different periods during the treatment. Surface tension,

interfacial tension, and emulsification/deemulsification results, as presented in Table I, showed that biosurfactants were present and have gradually disappeared as the biotreatment proceeded. Through gas and thin layer chromatography, compounds falling in the range of biosurfactants, were detected. These compounds with a structure close to the structure of glycolipids, accounted for 5,9 mg/g of sludge at the beginning of treatment and for 1,6 mg/g at the end of the treatment.

Additional experiments indicated that biodegradation can also be enhanced through the external addition of biosurfactants. The addition of sophorose lipids obtained through fermentation with Torulopsis bombicola produced a more complete elimination of the hydrocarbons in the sediments when compared to the controls.

Within the scope of this project, the technology was successfully demonstrated such that the cleanup objectives were met in a cost effective manner and the site could be reclassified. Evaluations for other sites and applications have to be performed on a case by case basis and require experience as well as careful judgement, each combination of contaminants and impacted matrix being characterized by its own behaviour, making simple transposition of results a hazardous exercise. The approach evaluated in this project nevertheless constitutes a significant development beyond conventional biotreatment methods and extends the field of application of bioremediation.

FOR MORE INFORMATION

The project was carried out by Sanexen Environmental Services Inc. with the collaboration of Huntsman Chemical Company of Canada Inc.

The information provided in this summary is based on a technical report prepared by Sanexen Environmental Services Inc., entitled: Développement et démonstration d'une technologie de biodégradation en phase semi-solide. Procédé de Biolyse [MD] avec dragage .

For more information, please contact:

Technology Development Section, Environment Canada (514) 283-9678

Direction de la coordination de la recherche, Environnement et Faune du Québec (418) 643-2073

Table 1 Test results on the sediments

Parameter	June 28	July 28	August 11	Sept. 3
Surface tension (mN/m)				
- aqueous supernatant	58,27	69,11	70,4	-
- organic extract	19,25	19,095	18,975	-
Interfacial tension (mN/m)	11,26	22,90	22,93	-
Emulsion half-life (min)	2,7 - 5,5	1,3 - 4,0	seconds	-
Mineral oil and grease (mg/kg)	13 500	2 110	-	920

DISCLAIMER/REVIEW NOTICE

This document has been reviewed by DESRT Federal-Provincial Comite for the Québec Region. The contents do not necessarily reflect the views and policies of agencies represented by DESRT. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

The National Contaminated Sites Remediation Program

DESRT Development and Demonstration of Site Remediation Technology

BIOREMEDIATION OF HYDROCARBON IMPACTED SOILS A COMPOSTING TECHNOLOGY DEMONSTRATION

CBCL Limited
Slemon Park , Summerside, Prince Edward Island

- PROJECT SUMMARY -

JULY 1995

INTRODUCTION

In 1989, the Canadian Council of Ministers of the Environment (CCME) acknowledged the need for a consistent - national approach for the prioritization and remediation of high risk contaminated sites in Canada. In response to this need, CCME established the National Contaminated Sites Remediation Program (NCSRP), which is supported and administered through federal-territorial bilateral agreements.

The DESRT (Development and Demonstration of Site Remediation Technology) program is a component of NCSRP. It was established to address the NCSRP objective of working with industry to stimulate the development and demonstration of new and innovative technologies with the potential to resolve problems that are critical to the environmental remediation of contaminated sites.

DESRT SUPPORTED TECHNOLOGY

CBCL Limited, in conjunction with the PEI Department of Agriculture proposed to evaluate composting as a means to remediate petroleum contaminated soil through the use of other organic waste materials. Financial support for the project was provided by the Canadian Petroleum Products Institute (CPPI) and jointly, by the PEI Department of Environment and Environment Canada, under the auspices of the DESRT Program. The DESRT Program provided $85,000 towards the $100,000 project cost.

TECHNOLOGY DESCRIPTION

Composting is a natural biologic process of decomposition where organic solid wastes are aerobically degraded into compost, a stable humus like substance which has useful properties as a soil conditioner. The processes involved stabilize the organics so they can be easily and safely handled, stored and applied to land without adverse environmental impact. The heat generated in the process destroys human pathogens. Thus composting is an engineered biological treatment system.

The application of hydrocarbon impacted soils(HIS) to composting as a treatment method has not been adequately addressed. In 1991 experimentation was carried out on HIS with potato wastes in PEI. The results were positive but additional work was required.

This study was carried out to determine if composting was a viable technology for the treatment of hydrocarbon impacted soils by integrating the HIS with the compostable fraction of municipal solid waste (MSW). The objective of the study was to carry out an actual field demonstration and to document the process. The impacted soils were mixed in varying volumetric measure with the compostable fraction of municipal solid waste from a nearby waste management utility and the degradation of the hydrocarbon was monitored.

TECHNOLOGY DEMONSTRATION SUMMARY

The demonstration involved the acquisition of HIS and MSW. The soils were obtained locally and were described as very fine silty sands. Diesel oil was added to the soils onsite to a targeted concentration of 5000 mg/kg. The compostable solid waste was obtained from a successful local municipal composting operation.

A total of eight windrow piles were developed at the site (Figure 1). Each pile was approximately 20 feet long and 8 feet wide with a height of 5 to 6 feet. Three piles were to be used as control piles(including a static unturned pile, a turned pile, a biopile and a 100% MSW pile). The remaining four piles were used to measure the impact of increasing the volume of HIS to MSW from a ratio of 10% HIS to 90% MSW by volume in pile 1 to 40% HIS to 60% MSW by volume in pile 5.

Piles 1 through 6 were turned on a regular basis throughout the duration of the project. The turning was carried out by a local contractor using a Wildcat windrow turner driven by a 110 hp tractor. Piles 7 and 8 were left unturned. Only the biopile was covered for the duration of the project.

Monitoring the piles involved recording physical observations and odours, and collecting gas readings using a variety of methods including hand held surveyors, tedlar bag samples and carbon desorption tubes. Soil samples were analyzed for total petroleum hydrocarbons (TPH), BTEX and metals.

Each pile was provided a poly sheet with leachate collection system to monitor the formation of leachate throughout the project.

The project was initiated on October 5 with the final results collected December 21, 1994. The ambient temperature at the demonstration site effectively ended operation past the first week in December.

DEMONSTRATION RESULTS

A summary of the key results of the study are shown in Table 1. The table indicates the level of treatment accomplished following the study. Removal rates as high as 97% were attained and the composting was found to be more effective than the biopile control.

Analysis of the remaining compost in piles 1 through 5 also indicated that the compost met guidelines for unrestricted compost application. Composting of oily soils is an effective process and has inherent advantages over biopiles.

This project opens the door for the integration of HIS treatment into existing and proposed compost operations at local, municipal and industrial sites. Other waste streams in addition to compost may be considered and could include sewage sludge, hay, sawdust, etc.

Table 1 - Removal of Fuel Oils and TPH in the Experimental Piles

Pile and Treatment	Removal of TPH (%)	Removal of Fuel Oil (%)
Pile 1: 100% compost	97	98
Pile 2: 90% v/v compost	97	97
Pile 3: 80% v/v compost	93	92
Pile 4: 70% v/v compost	90	92
Pile 5: 60% v/v compost	88	90
Pile 6: 0% v/v compost, turned control	65	68
Pile 7: 0% v/v compost, biopile	70	75
Pile 8: 0% v/v compost, unturned control	20	40

STATUS

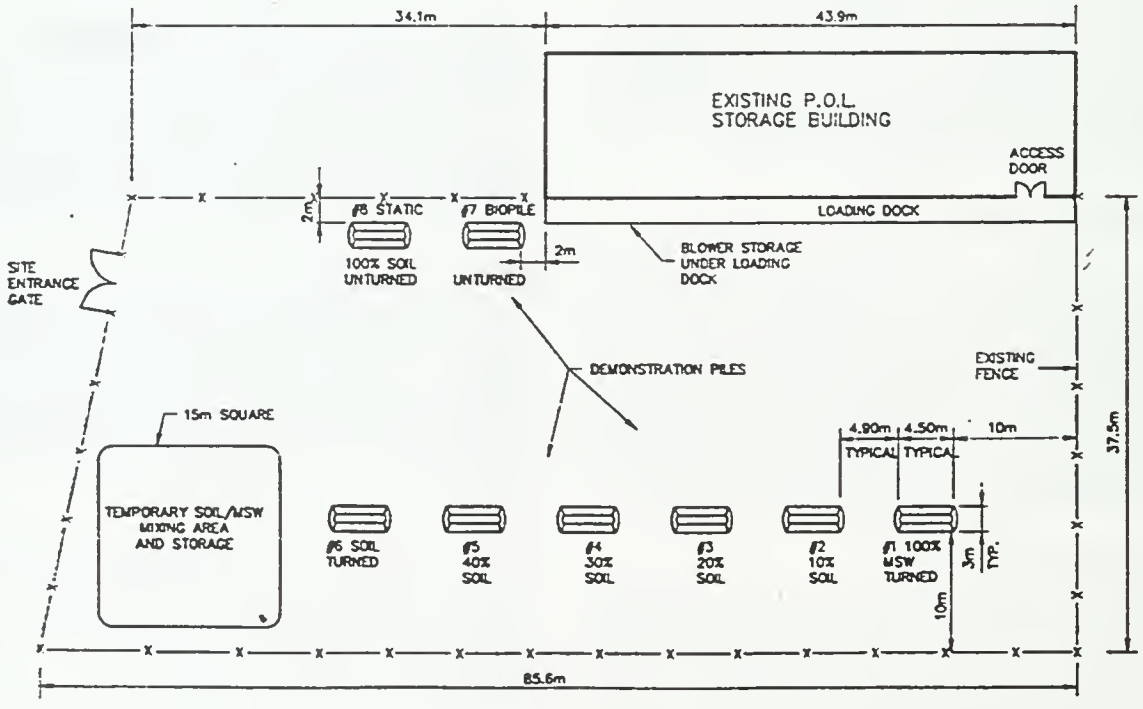
A final report has been submitted and is currently being reviewed.

FOR MORE INFORMATION

The information provided in this summary was provided by Mr. Bruce Strum, formerly of CBCL Ltd. For more information, please contact:

L. Keller, Environment Canada, (819) 953-0962
Don Jardine, PEI Dept. of Environmental Resources (902) 368-5035
W. J. D'Eon, P. Eng. , CBCL Ltd., (902) 421-7241

Figure 1:



DISCLAIMER/REVIEW NOTICE

This document has been reviewed by the Environmental Technology Advancement Directorate of Environment Canada. The contents do not necessarily reflect the views and policies of agencies represented by DESRT. Mention of trade names or commercial products does not constitute a recommendation or endorsement for use.

Environment Environnement

TABLE 1. METALS REMOVAL FROM SOIL USING DIFFERENT EXTRACTANTS (PHASE I STUDY)

TASK	TEST NO.	REAGENT	WASH TIME	# OF CYCLES	REMOVAL % **			
					Cd	Cu	Pb	Zn
Metal Screening	1-1	Hot Water (40°C)	2 hrs	1	0	0	50	0
	1-2	HCl (pH 2)	2 hrs	1	61	32	63	35
	1-3	Verseen Tetra (10%)	2 hrs	1	56	35	63	25
	1-4	Kalex Liquid (10%)	2 hrs	1	43	28	75	6
	1-5	Sequential: Hot Water (40°C) HCl (pH 2) Verseen Tetra (10%)	30 min. each	1 ea.	50	0	12	25
Metal Final	2-1	Kalex Liquid (10%)	4 hrs	2	57	27	57	22
	2-2	Kalex Liquid (10%)	4 hrs	1	41	13	54	19
	2-3	Kalex Liquid (20%)	4 hrs	1	52	4	46	19
	2-4	Kalex Liquid (10%)	8 hrs	1	54	0	37	23
	2-5	Sequential: Verseen Tetra (10%) HCl (pH 2)	2 hrs each	1 ea.	63	35	49	28
	2-6	Kalex Liquid (10%)	24 hrs	1	52	25	54	28

* rinse time, settling time, and decantation time not included
** on dry weight basis

TABLE 2. METALS AND PCB REMOVAL FROM SOIL USING DIFFERENT SURFACTANTS (PHASE II STUDY)

TASK	TEST NO.	REAGENT	WASH TIME	# OF CYCLES	REMOVAL % **				
					Cd	Cu	Pb	Zn	PCB
PCB Screening***	3-1	Olin 4750 (0.25%)	10 min	1	47	25	21	25	25
	3-2	Redicote E-11 (0.25%)	10 min	1	52	47	42	41	46
	3-3	Witconate 1223L (0.25%)	10 min	1	47	46	21	32	33
	3-4	Tween 80 (0.25%)	10 min	1	43	16	0	39	8
PCB Final***	4-1	Redicote E-11 (0.5%)	10 min	1	37	25	59	34	52
	4-2	Redicote E-11 (0.5%)	10 min	2	0	12	17	12	0
	4-3	Redicote E-11 (0.5%)	30 min	1	0	1	44	0	0
	4-4	Redicote E-11 (0.5%)	45 min	1	35	38	15	38	42

* rinse time, settling time and decantation time not included
** on dry weight basis
*** relative removal rates only

TABLE 3. PCB REMOVAL FROM SOIL USING DIFFERENT BIOSLURRY REACTOR TREATMENTS (PHASE III STUDY)

REACTOR	DESCRIPTION	CONCENTRATION (mg/kg)		% REMOVAL
		Initial (1991/11/22)	Final (1992/04/01)	
1	Raw soil + aerobic seed + nutrients	1575	2306	0
2	Pretreated soil + aerobic seed + nutrients	1193	702	41
3	Pretreated soil + air sparging	1193	719	40
4	Pretreated soil + surfactant	1193	954	20
5	Pretreated soil + anaerobic seed + glucose + nitrogen blanket	1193	708	41

Table 1. Summary of Near-Real-Time Monitoring (NRTM) Techniques

NRTM Technique	Studied Contaminants	Comparative Technique	Major Findings	
			Advantages	Disadvantages
Supercritical Fluid Extraction (SFE)	PAHs and CPs	Soxhlet extraction	Faster than Soxhlet[1] Field transportable Minimal solvent usage	Wet soil needs to be dried Operating costs higher than Soxhlet[2] Low recoveries from some analytes
Immunoassay Technology	PAHs, PCBs, and CPs	Soxhlet extraction and GC/MS or GC/ECD	40 to 200 samples/day More cost effective[3] Good correlations with comparative techniques: PCB (86%), PAH (82%), PCP (89%)	False negative results (10 to 20%) Confirmatory analyses required Cross reactivity with other analytes
Solid Phase Microextraction	BTEX	Headspace with GC/FID detection	Field transportable Rapid (1 sample/hr) Full resolution of BTEX	Regulatory acceptance Cost[4] Non-selectivity of the FID detector
Rapid Extraction HPLC/Fluorescence	PAHs	Soxhlet extraction and GC/MS detection	Field transportable Fast (2 samles/hr) Cost effective[5]	Only partial resolution of PAHs
Microwave Assisted Digestions	Trace Metals	Hotplate digestion	Field transportable Fast (12 samples/hr) Results comparable to hotplate technique	High operating costs[6]
Energy Dispersive X-ray Fluorescence	Trace Metals	Hotplate digestion with AA or ICP detection	Field transportable Fast (5 samples/hr) Cost effective[7]	Sample preparation required Poor detection limits on some metals

[1]SFE capable of 8 samples/hr while Soxhlet requires overnight extraction. [2] Cost effectiveness of SFE is reflected in the increased number of samples analysed rather than a reduction in operating costs. [3]Immunoassay cost per sample will vary with the type of kit used and the per diem cost of the field personnel, but on average, costs are 40 to 60% less than comparable methods performed in the laboratory. [4]Cost per sample is comparable to BTEX analyses by headspace method. [5] Typical cost savings should approach 50% or more over conventional Soxhlet/GC/MSD. [6]Capital costs of the microwave and digestion vessels would make this method 5 to 10 times more costly than comparable hot-plate digestion. [7]Typical instruments are 30-40% of the cost of ICP-OES and since no sample digestion step is required, considerable savings should be realized.

The National Contaminated Sites Remediation Program

DESRT Development and Demonstration of Site Remediation Technology

EVALUATION OF SOIL WASHING AND BIOSLURRY REACTOR TREATMENTS FOR PCB-HEAVY METAL CONTAMINATED SOILS WASHBURN & GILLIS ASSOCIATES LTD.

Fredericton, New Brunswick

- PROJECT SUMMARY -

December 1993

INTRODUCTION

In 1989, the Canadian Council of Ministers of the Environment (CCME) acknowledged the need for a consistent national approach for the prioritization and remediation of high risk contaminated sites in Canada. In response to this need, CCME established the National Contaminated Sites Remediation Program (NCSRP), which is supported and administered through federal-provincial-territorial bilateral agreements.

The DESRT (Development and Demonstration of Site Remediation Technology) program is a component of the NCSRP, and was established to address the NCSRP objective to work with industry to stimulate the development and demonstration of new and innovative technologies having the potential to resolve problems which are critical to the environmental remediation of contaminated sites.

A technology process selected for participation in the DESRT program was a soil washing and bioslurry reactor treatment process for soils contaminated with a combination of both heavy metals and PCBs, which was developed by Washburn & Gillis Associates Limited. The study was conducted by Washburn & Gillis in association with Keystone Environmental Inc., and was jointly funded by Environment Canada, New Brunswick Environment, and the vendor.

SITE HISTORY

The site chosen for the soil for the bench-scale testing is a former metal scrap yard owned by Dominion Metal Ltd., located in Saint John, New Brunswick. The scrap yard, which is now owned by the New Brunswick Department of Transportation (DOT), was in operation from 1950 to 1974. Its operations included removal of metals such as copper, lead and zinc from electrical transformers. It is likely that some of the transformers also contained fluids with high levels of PCBs. It is believed that these fluids leaked into the soil together with dissolved heavy metals such as cadmium, copper, lead and zinc. It is estimated that at the site approximately 210-648 m^3 of soil is contaminated with PCBs and heavy metals.

DESRT SUPPORTED WORK

The DESRT program supported a bench-scale study to determine the feasibility of soil washing and bioslurry reactor techniques to remove PCBs and heavy metals from soil at the former scrap yard. High concentrations of both PCBs and heavy metals at this site prevented single remediation technologies from being considered as treatment options. The DESRT Program provided $215,000 towards this project.

TECHNOLOGY DESCRIPTION

The process developed by Washburn & Gillis Associates Ltd. was a three-phase approach for soil clean-up. The first phase involved the removal of heavy metals from the soil by soil washing, by creating a slurry of soil and water containing solvent or a surfactant in a vessel and agitating the mixture. The second phase consisted of a series of screening tests to identify the most effective surfactant for the removal of PCBs. The final phase was the removal of the PCBs using a bioslurry reactor operated under anaerobic and aerobic conditions.

TECHNOLOGY DEMONSTRATION SUMMARY

Soil samples exhibiting higher than average levels of contamination for the site were collected and prepared for testing. Near surface soils comprised primarily of gravel and sandy clay were collected with a stainless steel spoon. Soil preparation involved drying, mixing, splitting, and sieving to obtain relatively homogeneous test samples.

The assessment of treatment technologies was undertaken in three phases. Phase I consisted of a series of screening tests to identify the most effective extractant for the removal of metals and a second series of tests to optimize the experimental conditions. The tests were conducted using a jar test unit.

Phase II consisted of a series of screening tests to identify the most effective surfactant for the removal of PCBs and a second series of tests that evaluated the effects of increased wash cycle and extraction time on the process performance. In all Phase II tests, the test slurry was prepared at a soil to water ratio of 1:3 by weight. Phase II tests were conducted using a Denver soil washing unit.

Phase III consisted of the bioslurry reactor treatment and involved the setting up of five experimental reactors with different treatment conditions. The reactors were constructed from standard one-gallon glass jars. The jars were wrapped in aluminum foil to reduce light penetration into the reactors.

Five hundred grams (dry weight) of pretreated soil were placed in each reactor to which was added 2500 ml of tap water. Pretreatment included a surfactant wash, an NaOH rinse, an HCL wash and a tap water rinse.

The aerobic seed added to the reactors was obtained from supernatant collected from a four week aerobic seed reactor containing raw site soil. The anaerobic seed was obtained from an anaerobic sludge collected at a chlorine bleach paper mill. A variable-speed mixer with an impeller was placed in each reactor to provide constant mixing. After startup, daily monitoring was performed of the bioslurry reactors and included temperature, pH and dissolved oxygen measurements. Four reactors were operated for ten weeks and one for fourteen weeks. Test samples were analyzed for PCBs, metals, bacterial counts, moisture content, TOC, and chloride after startup and upon completion of the reactor studies.

DEMONSTRATION RESULTS

Results reported for the soil washing study in Table 1 show that acid extraction at a pH of 2 achieved the maximum overall removal of metals among the various extractants tested. Cadmium was reported to have been reduced from 22 mg/kg to 8.5 mg/kg; copper from 24,8000 mg/kg to 16,800 mg/kg; lead from 22,800 mg/kg to 8,420 mg/kg; and zinc from 4,130 mg/kg to 2,700 mg/kg.

Due to the superior wetting characteristics of Kalex liquid and the operational constraints associated with the use of hydrochloric acid (e.g. fume emission), Kalex liquid was eventually selected as the metal extractant of choice.

The results of the Phase II surfactant study are provided in Table 2. In the Phase II study, Redicote E-11 was reported to result in the greatest removal of PCBs and metals for the four surfactants tested. Use of Tween 80 was reported to have resulted in the lowest percent removal of contaminants. Follow-up tests with Redicote E-11 at double the initial concentration reportedly indicated greater removal of PCBs, lead and zinc. Increasing wash time and wash cycles reportedly did not enhance recovery of contaminants. The Phase III study results are presented in Table 3, and show estimated PCB removal rates for the five bioslurry reactor treatments. Treatment 2 (pretreated soil + aerobic seed + nutrients) was reported to have resulted in the greatest percent reduction in PCBs (41%).

STATUS

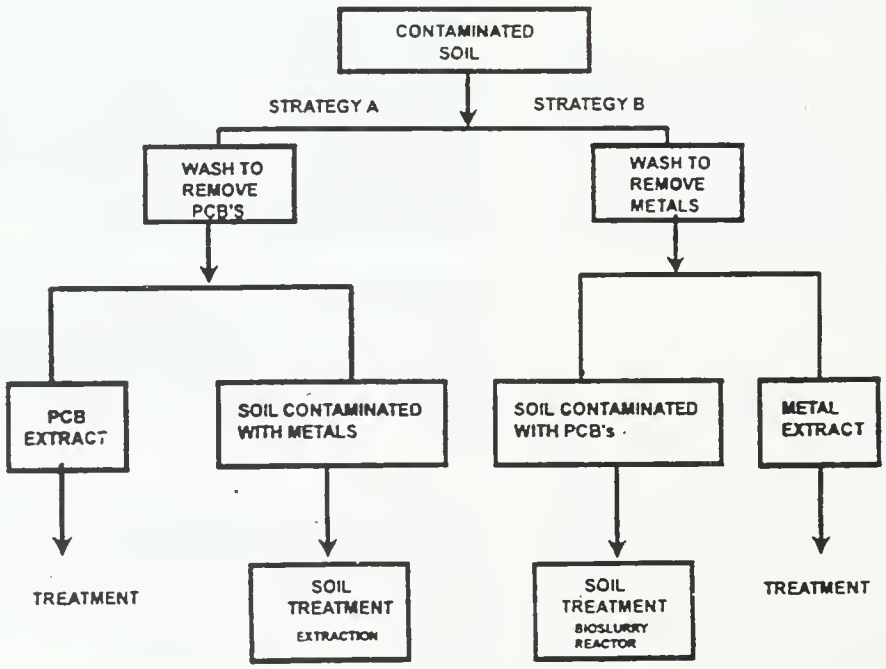
The soil washing and slurry bioreactor treatability study was completed in the fall of 1992. A final report has been submitted and approved by the technical review committee.

Project Summary prepared by Wastewater Technology Centre for:
DESRT Program, Technology Development Directorate
Environmental Protection Service, Environment Canada
Hull, Quebec

In cooperation with:
New Brunswick Environment

For Further Information Contact:
G. Hardy, Environment Canada (819) 953-0962
L. Steward, NB DOE (506) 457-4848

FIGURE 1. SOIL WASHING / TREATMENT DIAGRAM



DISCLAIMER/REVIEW NOTICE
This document has been reviewed by the Technology Development Directorate of Environment Canada. The contents do not necessarily reflect the views and policies of agencies represented by DESRT. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

The National Contaminated Sites Remediation Program

DESRT Development and Demonstration of Site Remediation Technology

-Project Summary-

AN ASSESSMENT OF AIR FLOW CHARACTERISTICS OF FRACTURED SANDSTONE BEDROCK AND APPLICATION OF AIR SPARGING AT A PETROLEUM CONTAMINATED SITE

ADI NOLAN DAVIS
Fredericton, New Brunswick

June 1995

Introduction

In 1989, the Canadian Council of Ministers of the Environment (CCME) acknowledged the need for a consistent national approach for the prioritisation and remediation of high risk contaminated sites in Canada. In response to this need, CCME established the National Contaminated Sites Remediation Program (NCSRP), which is supported and administered through federal-provincial-territorial bilateral agreements.

The DESRT (Development and Demonstration of Site Remediation Technology) Program is a component of the NCSRP, and was established to address the NCSRP objectives. These objectives consist of working with industry to stimulate the development and demonstration of new and innovative technologies having the potential to resolve problems that are critical to the environmental remediation of contaminated sites.

A research project selected for participation in the DESRT program was the study of air flow characteristics of fractured sandstone bedrock and the application of air sparging at petroleum contaminated site.

Technology Application

Many contaminated sites have hydrocarbons adsorbed within the soil and fractured sedimentary bedrock above the groundwater table. Air sparging has the potential to not only expedite the rate of remediation, but to clean sites to a lower level of contamination than with only a pump and treat system. Contaminated sites with underlying fractured bedrock provide a particular challenge due to the unpredictable migration of potentially explosive vapours along bedrock joints and fractures. As a result, the application of air sparging must include the installation of a properly engineered vapour extraction system (VES) to capture and eliminate the vapour plume.

DESRT Supported Work

The study is being carried out by ADI Nolan Davis and is jointly funded ($68 000) by Environment Canada and the New Brunswick Department of the Environment under the DESRT program.

The goal of the project is to develop a generic methodology to delineate the air flow and gas diffusion characteristics of unsaturated zones located in fractured sedimentary bedrock through the completion of a tracer gas study. The interpreted migration patterns of the tracer gas will be used to predict the movements of the vapour plume formed by sparging. The on-going sparging system will be monitored to determine its efficiency to remediate hydrocarbon contamination.

Site Description

The site for this project is a former service station located in Chatham, N.B. The stratigraphy consists of 0.5 to 2.0 m of granular soils overlying fractured sandstone bedrock. The groundwater table is located within the bedrock at about 2 to 3 m below the ground surface, with petroleum contamination detected within the bedrock, in both saturated and unsaturated zones.

The remediation of the site was initiated in November 1994 with the removal of contaminated soil and some of the weathered bedrock within a limited area. Based on the DESRT support for this air sparging study, the site owner has apparently decided to implement an air sparging system as part of the site remediation program and tentatively replace the initially planned pump and treat system (air stripper). The installation and operation of the sparging system will be carried out in conjunction with this DESRT project.

Project Description

The project is divided into 5 components: drilling and installation of vapour monitoring probes, air permeability tests, tracer gas study, air sparging tests, interpretation and reporting. The probes were installed in December 1994, while the air permeability testing will be carried out in February 1995, and the tracer gas study during the spring of 1995.

Vapour Monitoring Probes Installation

Twenty vapour monitoring probes were installed within the vadose zone at twelve locations and to depths varying from 0.5 m to 3.5 m below ground surface. The vapour monitoring probes surround three sparging points which have a total of 7 sparging ports each. The vapour monitoring probes consist of 25 mm threaded PVC piping with a 0.5 m to 1.0 m screened section located at the base of the borehole. A coarse sand pack was placed around the screened section and a bentonite seal was placed on top of the gravel pack to limit the inflow of air from the surface.

Air Permeability Tests

Air permeability tests will be conducted within the vadose zone using vapour extraction techniques. The effects of air withdrawal will be monitored in adjacent (monitoring) wells in order to determine the air permeability and the radius of influence. This will provide an indication of expected results from the tracer gas study. Methane levels will be measured in order to obtain a background level prior to the tracer gas study being carried out.

Tracer Gas Study

A vadose zone tracer gas study will entail the injection of an easily detected inert gas into differing locations within the vadose zone at varying distances away from the vapour extraction well. The vapour extraction well will be subsequently monitored for the detection of the gas. The temporal and spatial movement of the tracer gas, in the subsurface, will be monitored through the vapour monitoring probes.

Two gases are being evaluated for use in the study: sulfur hexafluoride (SF_6) and methane. Methane is more practical for regular field application since it does not require the use of a gas chromatograph, as does the SF_6. However, the detection of high background concentrations would prevent the use of methane as a tracer gas. The choice of the tracer gas will be finalized based on the background methane concentrations measured during the air permeability testing.

In order to perform the tests, a measured volume of tracer gas will be injected at a rate of approximately 5-10 litres per minute (L/min). Tracer gas volumes will be measured utilizing standard, low-flow capacity flowmeters. Once the void volume of the injection point are filled with tracer gas, the flow rate of the gas will be reduced to avoid a significant local pressure change at the injection point. During and following injection of the tracer gas, the extraction well discharge will be monitored with a continuous monitoring detector. The tracer gas 'travel time' within the subsurface is the primary parameter being sought in this study.

Air Sparging Test

Based on the flow characteristics obtained from the air permeability tests and the tracer gas study, predictable flow patterns in the vadose zone will be identified. The air flow patterns that might be identified will be used to assess the effectiveness of the tracer gas study for the implementation of air sparging in fractured bedrock.

Status

A final report and a field manual detailing all procedures utilized during the project is expected in the summer of 1995.

This Technical Summary Sheet was prepared
by ADI Nolan Davis for:
The DESRT Program, Technology Development Directorate
Environmental Protection Service, Environment Canada,
Hull, Quebec

In cooperation with:
New Brunswick Department of the Environment

For further information on this project or the National Contaminated Sites Remediation Program, please contact:

M.D. Riley, Vice-President, ADI Nolan Davis Inc.
(506) 458-9770

Louise Steward, NBDOE
(506) 457-4848

Rita Mroz, Environment Canada
(902) 426-9405

Lisa Keller, Environment Canada
(819) 953-0962

DISCLAIMER/REVIEW NOTICE:

This document has been reviewed by the Technology Development Directorate of Environment Canada. The contents do not necessarily reflect the views and policies of agencies represented by DESRT. Mention of trade names or commercial products does not constitute recommendations or endorsement for use.

The National Contaminated Sites Remediation Program

DESRT Development and Demonstration of Site Remediation Technology

- Project Summary -

Tracers in Fractured Porous Sandstone Flow Regimes

GEMTEC Limited
Fredericton, New Brunswick

June 1995

Introduction

In 1989, the Canadian Council of Ministers of the Environment (CCME) acknowledged the need for a consistent national approach for the prioritization and remediation of high risk contaminated sites in Canada. In response to this need, the CCME established the National Contaminated Sites Remediation Program (NCSRP), which is supported and administered through federal-provincial-territorial bilateral agreements.

The DESRT (Development and Demonstration of Site Remediaiton Technology) Program is a component of the NCSRP, and was established to address the NCSRP objectives of working with industry to stimulate the development and demonstration of new and innovative technologies having the potential to resolve problems which are critical to the environmental remediation of contaminated sites.

A research project selected for participation in the DESRT program was the study of chemical tracers in fractured porous sandstone for the characterization flow regimes. The study was jointly funded by Environment Canada and the New Brunswick Department of the Environment under the DESRT program.

Technology Application

Gemtec Ltd. is a New Brunswick owned and operated consulting company providing expertise on geotechnical engineering for structures, utilities and infrastructure, all aspects of the groundwater resource, its protection and remediation, and provides quality control and testing services for engineering construction.

The objective of the DESRT project will be to evaluate the use of chemical tracers, as a supplement to conventional hydraulic testing, in the characterization of fractured porous sandstone flow regimes.

Approximately one half of the province of New Brunswick is underlain by Pennsylvanian sandstone, a fractured and porous bedrock material which is often exploited for water supply purposes. The release of contaminants such as petroleum hydrocarbons into these aquifers poses a risk to nearby groundwater resources.

When conducting an assessment of the contaminant flow regime in these fractured porous sandstones, it is often difficult to predict flow directions and rates using conventional techniques. Hydraulic testing in the field can alternatively be supplemented by the introduction and monitoring of chemical tracers. Such an approach may lead to a better assessment of groundwater and contaminant flow through bedrock environments.

Site History

Field programs will be carried out at two sites in New Brunswick. At Site A, a gasoline-contaminated groundwater plume is currently being remediated by a pump and treat system. A forced-gradient tracer test will be carried out at this site. Site B will be an appropriately chosen sandstone quarry where the geology is well suited for natural and forced-gradient tracer tests.

DESRT Supported Work

Funding in the amount of $65,000.00 was provided by the New Brunswick Department of the Environment and Environment Canada. Provincial funding as made available through the Environmental Trust Fund.

Project Description

A protocol for tracer addition and monitoring in various hydrogeological settings will be established based on the results of bench scale and field studies. The laboratory work will involve column experiments and the determination of matrix characteristics of representative sandstone samples.

At both sites proposed for the study, average linear groundwater velocity and effective porosity will be determined. A model will then be developed for estimating the relationship between porosity and groundwater velocity based on intact and fractured sandstone characteristics.

Current Results

Following a literature review and bench-scale testing, the conservative groundwater tracer sodium bromide (NaBr) was chosen for the field testing. Bromide has been used successfully as a conservative groundwater tracer in several field studies including the Borden Tracer study. It behaves similarly to chloride but exists at much lower concentrations in most natural groundwater environments. Also, the bromide ion can be detected at concentrations of 0.5 mg/L using inexpensive portable equipment (Bromide (Br^-) can be detected in groundwater by specific conductance but the total dissolved solids (TDS) are too high to use this method at the proposed field sites). Instead, a procedure using spectrophotometry was refined, permitting analysis of a large number of groundwater samples in the field. The two analytical methods were compared in the laboratory column tests. The results are shown below.

The column tests were performed using a constant head permeameter apparatus. The column was filled with a uniform sand and steady flow conditions were achieved prior to introducing the tracer. The tracer was then introduced at a constant rate and concentration. Breakthrough curves were generated and used to calculate the groundwater velocity and dispersivity. The objectives of these column experiments were to confirm the bromide was a conservative tracer and to evaluate the spectrophotometry method which had been developed to measure bromide concentration. Column experiments using chloride and bromide produced similar breakthrough curves, confirming that the letter would be a suitable choice. It was also demonstrated that the chosen spectrophotometric technique could be used successfully in the field.

Prior to field testing, the New Brunswick Department of Health and Community Services (NBDHCS) was consulted for their input since existing toxicity data indicated that at high concentrations (>580 mg/L), bromide produces toxic effects in laboratory animals.

The NBDHCS reviewed the use of sodium bromide (NaBr) as a groundwater tracer and ruled that its use could not be supported on toxicological grounds.

Status

The bench-scale component of the work is now complete. Rhodamine (Wt) is now being considered as a replacement tracer dye although the non-conservative nature of this compound renders it less suitable for the intended purpose. Field work has been halted until this matter can be resolved. An old quarry site was developed for tracer testing but the site was abandoned due to vandalism. Other field quarry sites are currently being evaluated.

This Project Description was prepared by Gemtec Limited for:
The DESRT Program, Technology Development Directorate
Environmental Protection Service, Environment Canada, Hull, Quebec

In cooperation with:
The New Brunswick Department of the Environment

For further information on this project or the National Contaminated Sites Remediation Program, please contact:

Geoff R. Dickson, P.Eng, - Gemtec Ltd.
(506) 453-1025

Louise Steward, NBDOE
(506) 457-4848

Rita Mroz, Environment Canada
(902) 426-9405

Lisa Keller, Environment Canada
(819) 953-0962

DISCLAIMER/REVIEW NOTICE:

This document has been reviewed by the Technology Development Directorate of Environment Canada. The contents do not necessarily reflect the views and policies of agencies represented by DESRT. Mention of trade names or commercial products does not constitute recommendations or endorsement for use.

New Nouveau Brunswick
Environment / Environnement

The National Contaminated Sites Remediation Program

DESRT Development and Demonstration of Site Remediation Technology

-Project Summary-

PEAT MOSS BIOFILTER STUDY

GEMTEC Limited
Fredericton, New Brunswick

June 1995

Introduction

In 1989, the Canadian Council of Ministers of the Environment (CCME) acknowledged the need for a consistent national approach for the prioritization and remediation of high risk contaminated sites in Canada. In response to this need, the CCME established the National Contaminated Sites Remediation Program (NCSRP), which is supported and administered through federal-provincial-territorial bilateral agreements.

The DESRT (Development and Demonstration of Site Remediaiton Technology) Program is a component of the NCSRP, and was established to address the NCSRP objectives to work with industry to stimulate the development and demonstration of new and innovative technologies having the potential to resolve problems which are critical to the environmental remediation of contaminated sites.

A research project selected for participation in the DESRT program was the study of peat moss as filters in leachate management. The study was jointly funded by Environment Canada and the New Brunswick Department of the Environment under the DESRT program.

Technology Application

Gemtec Ltd. is a New Brunswick owned and operated consulting company providing expertise on geotechnical engineering for structures, utilities and infrastructure, all aspects of the groundwater resource, its protection and quality control and testing services for engineering construction.

The main objective of the DESRT project was to evaluate the use of peat moss for the decontamination of groundwater at or near waste disposal sites. Peat moss is an abundant resource in New Brunswick and its use presents a cost effective alternative for removing contaminants such as heavy metals, nutrients and organic compounds from groundwater.

Background

The potential for groundwater contamination due to leachate from uncontrolled solid waste disposal sites (dumps) is a widespread environmental concern. It is therefore important that treatment technologies be developed to effectively control and decontaminate groundwater at or near these sites.

In New Brunswick, NBDOE is currently implementing a program to close more than 150 dumps in the province, to be replaced by a number of regional waste management facilities. Although the dumps will be decommissioned following strict guidelines, the protection of surrounding groundwater resources remains a concern.

DESRT Supported Work

Gemtec Ltd. received funding from the DESRT program to carry out a study to evaluate the potential of New Brunswick peat moss as a filter in the management of landfill leachate. Total funding of $35,000.00 was provided by New Brunswick Department of the Environment and Environment Canada. Provincial funding was made available through the Environmental Trust Fund.

Project Description

Phase one of the project consisted of bench-scale experiments to evaluate the filtering capacity of New Brunswick sphagnum peat and to determine optimum operating conditions for full-scale systems. Vertical columns packed with peat were used to assess the effects of bed thickness, organic loading, bed compaction, hydraulic loading and changes in leachate parameters such as pH. The potential life of the peat biofilters and the advantages of operating several biofilters in series was also studied.

Phase two will involve construction of a larger scale biofilter unit at one of the dump sites in the province. The impacts of conditions such as precipitation and freezing temperatures will be studied. Finally, disposal options for spent filters will be evaluated and overall operating costs for biofilter systems will be estimated.

Demonstration Results

The results to date indicate that sphagnum peat can be used effectively to treat leachate and contaminated groundwater at waste disposal sites. The contaminant removal rates, achieved to date, are listed in Table 1.

Other data suggests that, in general, there is no significant difference in treatment efficiency for high (12 cm/d) and low (4 cm/d) hydraulic loading rates. There is, however, a marked difference in performance with bed depth; higher removal rates being observed in the 60 cm versus the 30 cm columns.

Compaction of the bed did not appear to have an impact on removal rates, however, higher bed compaction caused significant flow resistance through the column.

The data to date strongly suggests that peat biofilters either alone or in combination with other stages of treatment will meet current regulatory standards.

Status

The bench-scale phase of the work has been completed. The field component of the study will be initiated in April, 1995.

This Technical Summary Sheet was prepared by Gemtec Limited for:
The DESRT Program, Technology Development Directorate
Environmental Protection Service, Environment Canada, Hull, Quebec

In cooperation with:
New Brunswick Department of the Environment

For further information on this project or the National Contaminated Sites Remediation Program, please contact:

Louise Steward, NBDOE
(506) 457-4848

Robert Lutes, P.Eng - Gemtec Ltd.
(506) 453-1025

Lisa Keller, Environment Canada
(819) 953-0962

Table 1 Biofilter Effluent Quality vs. Hydraulic Loading

	Raw Leachate	Hydraulic Loading			Bed Thickness		Bed Compaction (gm/cm^3)	
		4 cm/d	8 cm/d	12 cm/d	30 cm	60 cm	0.20	0.25
Total Suspended Solids	130	3	3	7	20	6	2	3
Biochemical Oxygen Demand	940	2	2	9	300	4	4	3
Chemical Oxygen Demand	1500	190	420	640	630	160	350	400
Chromium	12.7	0.02	0.02	0.02	3.2	0.00	0.00	0.00
Nickel	0.02	0.02	0.02	0.02	0.00	0.00	0.01	0.00
Iron	89.7	0.13	0.45	0.37	0.09	0.06	0.09	0.10
Copper	0.0	0.0	0.0	0.0	0.00	0.00	0.01	0.01
Zinc	0.09	0.05	0.03	0.02	0.08	0.15	0.12	0.06
pH	6.84	3.44	3.61	4.11	2.98	2.97	3.06	3.06

All results except pH are in mg/L

DISCLAIMER/REVIEW NOTICE:

This document has been reviewed by the Technology Development Directorate of Environment Canada. The contents do not necessarily reflect the views and policies of agencies represented by DESRT. Mention of trade names or commercial products does not constitute recommendations or endorsement for use.